ICT AND DISASTER RISK REDUCTION DIVISION

In-Depth Study on the Design and Implementation Plan of Internet Exchange Points in CLMV Countries

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Abbreviations and Acronyms

AAE-1	Asia–Africa–Europe–1
AAG	Asia-America Gateway
AP-IS	Asia-Pacific Information Superhighway
APG	Asia-Pacific Gateway
BGP	Border Gateway Protocol
CDN	Content Delivery Network
CLMV	Cambodia, Lao PDR, Myanmar, Viet Nam
CNX	Cambodia Network Exchange
ESCAP	Economic and Social Commission for Asia and the Pacific
Gbps	Gigabit per Second
GMS	Great Mekong Subregion
HVAC	Heating, Ventilation and Air Conditioning
ICT	Information and Communications Technology
IDC	Internet Data Centre
IP	Internet Protocol
IPv6	Internet Protocol Version 6
ISP	Internet Service Provider
ITU	International Telecommunication Union
IXP	Internet Exchange Point
KISA	Korea Internet and Security Agency
KIXP	Kenya Internet Exchange Point
LANIC	Lao National Internet Center
Mbps	Megabit per Second
MCT	Malaysia–Cambodia–Thailand
MMIX	Myanmar Internet Exchange
ms	Millisecond
NIA	National Information Society Agency
OECD	Organisation for Economic Co-operation and Development
PoP	Point of Presence
RU	Rack Unit
SEA-ME-WE3	South-East Asia–Middle East–Western Europe–3
Tbps	Terabit per Second
UPS	Uninterruptible Power Supply
USD	United States Dollar
VNIX	Viet Nam National Internet Exchange
VNNIC	Viet Nam Internet Network Information Center
VNPT	Viet Nam Posts and Telecommunications Group
VoIP	Voice over Internet Protocol

Abstract

The broadband Internet in Asia and the Pacific has witnessed phenomenal growth in the last decade but there have been significant gaps among member countries of the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP). While ESCAP launched the Asia-Pacific Information Superhighway (AP-IS) initiative to narrow the digital divide and expand broadband Internet access, Cambodia, Lao PDR, Myanmar and Viet Nam (CLMV) continue to experience lower fixed-broadband subscriptions than other countries in the region. Although CLMV countries have seen rapid growth in the mobile broadband segment, insufficient wired network infrastructure and inefficient Internet traffic management have contributed to a relatively high cost structure and low broadband subscription.

Recognizing the challenges, ESCAP and the National Information Society Agency (NIA) of the Republic of Korea conducted a study in CLMV countries as part of the AP-IS initiative from 2017 and published results of the study in 2020. The study recommended, among other actions, the establishment of Internet exchange points (IXPs) to reduce data transit costs and network latency, and help increase Internet uptake and quality of service.

This working paper builds on the 2020 ESCAP-NIA study and analyses the challenges and opportunities for enhancing Internet traffic exchange and management systems in CLMV countries, as contribution towards the achievement of AP-IS goals. Following analysis of the network structure and traffic, and the existing IXPs in CLMV countries, the study proposes an inter-country IXP network topology and donor funding modality for IXP establishment. A cost estimate and guidelines for IXP establishment based on best practices are also provided. In summary, the study recommends the following:

- Deploy a ring-type inter-country IXP network topology and establish an IXP hub for CLMV countries to promote stable and resilient interconnection among CLMV countries, with neighbouring countries such as Thailand, and internationally, attracting global content providers and strengthening cooperation.
- Establish at least one neutral IXP in each country's capital city as the optimum location for Internet service providers (ISPs) and content providers to connect with the IXP. Relatedly, it is recommended that an Internet data centre (IDC) is established with an IXP to provide better hosting facility to providers. Based on best practices, there should be at least two IXPs in each CLMV country for their stable and competitive operations.
- Adopt the donor financing model to leverage funds from multilateral development banks in collaboration with government and other stakeholders. The estimated total cost of establishing an IDC with IXP is USD20 million.
- Cooperate among CLMV countries and with stakeholders in neighbouring countries like Thailand to harmonize national ICT policies and standards, and provide an enabling environment for enhancing Internet traffic exchange and management. Accordingly, set up a working group or task force of CLMV and interested neighbouring countries, in alignment with the AP-IS initiative, to agree on actions to be taken and facilitate the signing of a Memorandum of Understanding among CLMV and neighbouring countries.

Overall, these recommendations aim to improve Internet traffic and network management through the establishment of a network of IXPs, towards more affordable, resilient, high-quality broadband access for all in CLMV countries. Recommendations of this working paper will be shared through various regional dialogue and platforms.

1. Introduction

Broadband connectivity and Internet usage in Asia and the Pacific have witnessed phenomenal growth in the last decade. However, a digital divide persists. Cambodia, Lao PDR, Myanmar and Viet Nam (CLMV) have lower fixed-broadband subscription rates than other countries in the region, with less affordable services. Although these countries have seen rapid growth in mobile-broadband subscriptions, inadequate backbone infrastructure and inefficient data traffic management practices continue to impact broadband access and use, and limit the benefits of the Internet.

The Asia-Pacific Information Superhighway (AP-IS) initiative, led by the United Nations Economic and Social Commission for Asia and the Pacific (ESCAP), is an intergovernmental platform that aims to improve regional broadband connectivity, lower broadband Internet prices and ultimately bridge the digital divide. A previous study conducted by ESCAP and the National Information Society Agency (NIA) of the Republic of Korea, as part of the AP-IS initiative, found that expanding the fixed-broadband infrastructure and establishing neutral Internet exchange points (IXPs) among CLMV countries would be needed to bridge the digital divide.[1]

This working paper builds on the previous study and analyses the challenges and opportunities for establishing IXPs to enhance connectivity, affordability and reliability of the backbone network in CLMV countries.

An IXP is a place where Internet service providers (ISPs) meet to exchange traffic via Border Gateway Protocol (BGP) peering. IXPs are a key component of the Internet infrastructure that enable networks to exchange traffic with each other. By keeping domestic Internet traffic local, IXPs help reduce international transit costs, reduce latency in the network and provide a better user experience. IXPs have proven to play an important role in bridging the digital divide and providing affordable Internet for all. Best practices have shown that IXP location and management should be neutral, and outside commercial or governmental influences. Yet, many parts of the Asia-Pacific region, including in CLMV countries, still lack neutral IXPs.

This working paper presents the results from an in-depth study conducted between November 2019 and February 2020. The research methodology is outlined in the next section, followed by a summary of a desktop review of related studies (Section 3), and outcome from the interviews conducted with key informants in CLMV countries (Section 4). Based on analysis of the network structure and traffic, and the existing IXPs in CLMV countries (Sections 5 to 8), and case studies from the Republic of Korea and Kenya (Section 9), the study proposes an inter-country IXP network topology and donor funding modality for IXP establishment to enhance interconnection among CLMV countries (Section 10). A cost estimate and guidelines for establishing a neutral IXP in each country that is hosted in an Internet data centre (IDC) are also provided. The paper ends with policy recommendations for the way forward.

[1] ESCAP, "In-Depth Study of the Asia-Pacific Information Superhighway in CLMV Countries", AP-IS Working Paper Series, March 2020. Available at https://www.unescap.org/resources/depth-study-asia-pacific-information-superhighway-clmv-countries.

2. Research Methodology

The research team comprising of staff from NIA, ESCAP and LG U+ spent four months from November 2019 to February 2020 carrying out this study to propose an IXP model and provide policy recommendations. The methodologies used include site surveys, key informant interviews and analysis of documentations published by ESCAP, Internet Society, International Telecommunication Union (ITU), NIA and Organisation for Economic Co-operation and Development (OECD). Prior to site surveys and face-to-face meetings, pre-interview questionnaires were sent out to key informants. During the visits to CLMV countries and face-to-face meetings, the interviews were semi-structured with guiding questions to clarify responses in the pre-interview questionnaire and collect further information.

Due to the COVID-19 pandemic, the collection of data and conduct of interviews were disrupted at the last stage of the research. Nonetheless, the research team managed to complete the research study through the cooperation of ESCAP, private enterprises and government agencies.

3. Summary of Related Studies

There are three related studies that this working paper builds upon. The first is the 2020 ESCAP-NIA study mentioned above. The second is an ESCAP-commissioned research study conducted by Xi'an University of Posts and Telecommunications on network planning for the Greater Mekong Subregion (GMS).[2] The third is a study by OECD on information and communications technology (ICT) connectivity in South-East Asia.[3]

3.1 ESCAP-NIA Study

The 2020 ESCAP-NIA study identified that the digital divide is widening in CLMV countries. Based on 2019 data from ITU,[4] the fixed-broadband subscriptions per 100 inhabitants in Cambodia (1.12), Lao PDR (1.06) and Myanmar (0.24) is much lower than the average for Asia and the Pacific at 14.3 fixed-broadband subscriptions per 100 inhabitants. Only Viet Nam's performance is slightly above average with 15.35 fixed-broadband subscriptions per 100 inhabitants. Besides Viet Nam, the other three countries have made slow progress in raising fixed-broadband subscription rates in the past decade.

Although mobile-broadband expansion in CLMV countries has been rapid and mobile phones have become the means to access the Internet for an increasing number of people, mobile networks are dependent on fixed networks to meet the increasing demand for high-speed and high-quality data transmissions.

Available data shows that fibre-optic connectivity between CLMV countries has expanded in recent years, but the direct exchange of Internet traffic appears limited. In CLMV countries, Internet traffic exchange continues to take place at the points of presence (PoPs) of global transit providers. There is no mutually agreed policy on traffic management between CLMV countries, and in the absence of efficient Internet traffic management, tromboning[5] is a serious issue in CLMV countries, in which local Internet traffic is routed over international networks, resulting in high transit costs. This in turn affects the affordability and quality of Internet services for end users. The ability to have more direct routes is becoming more relevant in CLMV countries as Internet users access bandwidth-heavy content, such as videos or services like voice-over Internet protocol (VoIP), which have a low tolerance for latency.

In this context, the study recommended the establishment of a neutral IXP in each country, and the introduction of a mutually beneficial routing policy applicable to CLMV countries to facilitate intraregional exchange of Internet traffic to lower peering costs and improve Internet service quality. The study also recommended the establishment of an IDC with the IXP to introduce a content delivery network (CDN) and reduce unnecessary use of international circuit and extra hops to access content.

At least one fibre-optic connection between neighbouring countries (or top nodes) is recommended, which means a total of 12 links between CLMV and neighbouring countries. Ideally, dedicated links (physical or leased links) to an IXP or PoP is connected in a full mesh typology across all countries. For example, between Lao PDR and Thailand, an ISP in Lao PDR needs at least one line (physical fibre or capacity lease) to the IXP in Thailand and must

[2] ESCAP, "Research Report on the Network Planning for the Greater Mekong Subregion", AP-IS Working Paper Series, February 2020. Available at https://www.unescap.org/resources/research-report-network-planning-greater-mekong-subregion.

[3] OECD, *Southeast Asia Going Digital: Connecting SMEs* (Paris, 2019). Available at http://www.oecd.org/going-digital/southeast-asia-connecting-SMEs.pdf.

[4] ITU, "Statistics". Available at https://www.itu.int/en/ITU-D/Statistics/Pages/stat/default.aspx.

[5] World Bank and ITU refer to tromboning as follows: "In some cases, where there is no local or regional facility for the exchange of Internet traffic, developing country ISPs must pay for international transit facilities to deliver local traffic." See World Bank, InfoDev and ITU, *Telecommunications Regulation Handbook: Tenth Anniversary Edition* (2011), p. 146. Available at https://www.itu.int/pub/D-PREF-TRH.1-2011.

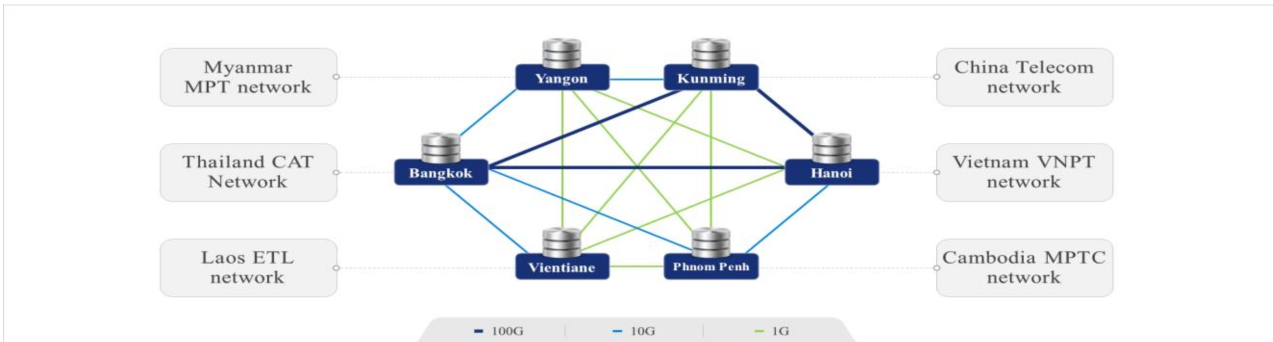
build a Lao PDR PoP owned by the ISP. This deployment allows Internet users in Lao PDR to directly access the ISP in Thailand through Thailand's IXP without an intermediary, thus minimizing unnecessary hops and improving service quality.

3.2 Xi'an University Study

An ESCAP-commissioned study by Xi'an University of Posts and Telecommunications proposed similar recommendations to the 2020 ESCAP-NIA study, which included the improvement of interconnection among GMS countries (comprising of Cambodia, Lao PDR, Myanmar, Viet Nam, Thailand and China) as part of the effort to optimize network management in the GMS.

This study was based on findings from an ESCAP report showing that countries in South-East Asia have relatively weak interconnections, insufficient terrestrial fibre-optic cable development, excessive dependence on submarine cables, and high transport and Internet transit costs. To address these challenges, Xi'an University of Posts and Telecommunications predicted the amount of Internet traffic by 2022 and accordingly, proposed an Internet network configuration for GMS countries that stressed the importance of cooperation among GMS countries in establishing interconnections (Figure 1).

Figure 1: GMS Internet networking structure



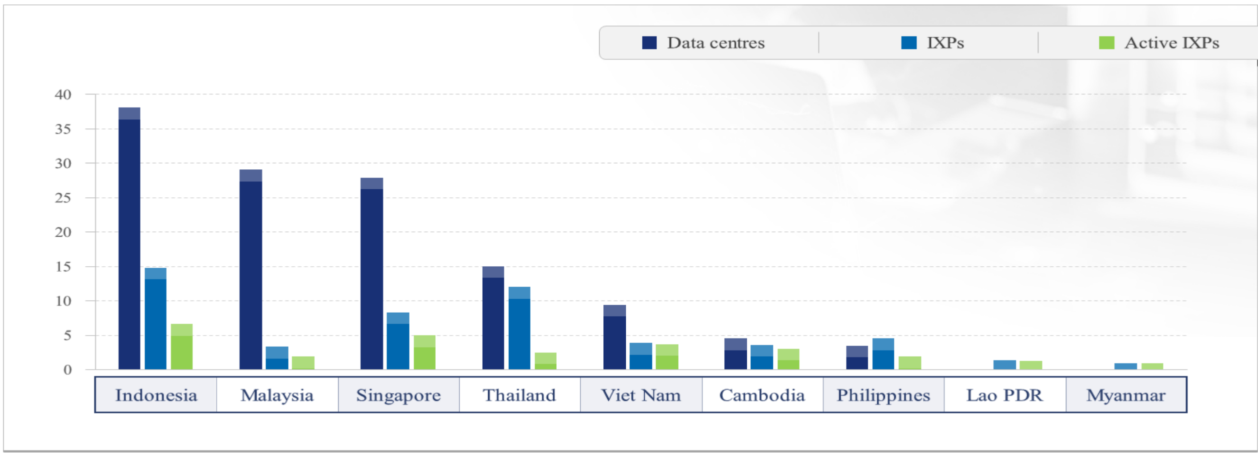
Source: ESCAP, "Research Report on the Network Planning for the Greater Mekong Subregion", AP-IS Working Paper Series, February 2020. Available at https://www.unescap.org/resources/research-report-network-planning-greater-mekong-subregion.

This study proposed the formation of a GMS-IS Steering Group for intergovernmental negotiations and network policy and planning to enable the implementation of the recommendations and enhance cooperation among GMS countries in achieving AP-IS goals. The study also proposed the formation of a GMS-IS Implementation Group to oversee the planning, financing, training and cooperation between operators in implementing the recommended network system, and the signing of a Memorandum of Understanding among the participating operators in the GMS countries to ensure clarity on the expected roles and responsibilities.

3.3 OECD Study

The OECD study provided policy recommendations for digital transformation in South-East Asia, particularly to foster the growth of small- and medium-sized enterprises. It stated that IXPs and IDCs are two important elements enabling efficient management of Internet traffic. Figure 2 from the study shows that Indonesia, Malaysia and Singapore are far ahead of other South-East Asian countries in terms of the number of IXPs and IDCs, while CLMV countries lag behind others in the region.

Figure 2: Number of IXPs and IDCs in South-East Asia, 2018



Source: OECD, Southeast Asia Going Digital: Connecting SMEs (Paris, 2019). Available at http://www.oecd.org/going-digital/southeast-asia-connecting-SMEs.pdf.

Generally, the number of IXPs are increasing in South-East Asia (Table 1). Indonesia has strengthened its connectivity by increasing the number of IXPs from four to seven. Cambodia, Malaysia, Myanmar, the Philippines, Singapore and Thailand have all added one new IXP between 2017 and 2018. The IXP expansion in South-East Asia should help to advance the routing of Internet traffic in the subregion, improve network performance and lower costs for all stakeholders.

Table 1: The number of IXPs in South-East Asian countries in 2017 and 2018

Country	June 2017	June 2018	Net change	% change
Indonesia	4	7	3	75
Singapore	4	5	1	25
Viet Nam	3	3	0	0
Cambodia	1	2	1	100
Thailand	1	2	1	100
Malaysia	0	1	1	100
Philippines	0	1	1	100
Lao PDR	1	1	0	0
Myanmar	0	1	1	100
Brunei	0	0	0	0

Source: OECD, Southeast Asia Going Digital: Connecting SMEs (Paris, 2019). Available at http://www.oecd.org/going-digital/southeast-asia-connecting-SMEs.pdf.

However, Table 2 shows that there are significant variations in the speed and latency experienced by South-East Asian countries depending on the measurement location. The best result was 50.1Mbps with 7.5ms latency, and the worst result was only 0.15Mbps with 230ms latency. The least performing routes can only support basic services such as text-based web services, which make it very difficult for small- and medium-sized enterprises to benefit from broadband services that utilize technologies such as artificial intelligence, big data, blockchain and e-commerce platform.

Table 2: Best and worst traffic speeds in South-East Asia

	Download speed (Mbps)	Latency (ms)
Worst	0.15	230
Best	50.1	7.5

Source: OECD, Southeast Asia Going Digital: Connecting SMEs (Paris, 2019). Available at http://www.oecd.org/going-digital/southeast-asia-connecting-SMEs.pdf.

Broadband quality in CLMV countries is relatively low compared to international benchmarks. To improve service quality, the study recommended improving regional backbone network connectivity in parallel with efforts to establish IXPs at national and subregional levels.

4. Outcome of Interviews

A summary of the face-to-face interviews with key informants in CLMV countries is provided below.

4.1 Cambodia

Agency	Sector	Date	Content
CFOCN	Fibre-optic cable construction / lease	18 Dec 2019	• The company is establishing a leased business by building fibre-optic networks throughout Cambodia, and it is continuously investing in Cambodia's broadband infrastructure with funds from the Asian Infrastructure Investment Bank. • For international network connection, CFOCN owns the landing station for the AAE-1 submarine cable network in Sihanoukville, and has terrestrial networks connecting to Viet Nam and Thailand. • CNX is a Cambodian IXP and ISPs operate their own IDCs but there is no neutral IDC.
Ministry of Post and Telecommunications	Government agency	18 Dec 2019	• Due to lack of resources, Cambodia relies on foreign providers to invest in Cambodia's local telecommunications business. • Development of wired networks is delayed compared to wireless networks.
Telecom Cambodia	1st wired telecommunications provider	19 Dec 2019	• There are five major ISPs and many small ISPs driving the Cambodian Internet industry. • CNX is a Cambodian IXP that handles domestic traffic. International traffic is routed through global transit providers.
Telcotech	ISP	20 Dec 2019	• Telcotech is a major ISP in Cambodia and has a domestic 11,000km fibre-optic cable network. • It has a landing station for the MCT submarine cable network in Sihanoukville. It has also invested in the AAG cable system, without a landing in Cambodia. • International traffic is routed through global transit providers, and domestic traffic is exchanged through CNX. It claims that CNX is a neutral IXP.
Camintel	2nd wired telecommunications provider	20 Dec 2019	• Information about Cambodia's telecommunications market and IXP/ISP status was shared.

Sein	Collection of local information	30 Jan 2020	• Information about Cambodia's network status and Internet plans and policies was shared. • Terrestrial and submarine network diagrams were confirmed.

4.2 Lao PDR

Agency	Sector	Date	Content
Sein	Collection of local information	30 Jan 2020	• Information about Lao PDR's ICT and policy status, terrestrial network diagram and ICT provider status was discussed.

4.3 Myanmar

Agency	Sector	Date	Content
Ministry of Transport and Communications	Government agency	31 Jul 2019	• Information about GIDC projects and the telecommunications market was shared.
Myanmar Posts and Telecommunications	1st wired / wireless telecommunications provider	30 Jul 2019	• Information about IXP status support request for wired and wireless telecommunications business was shared. • More information about the AP-IS initiative was requested.
Ooredoo	3rd wireless telecommunications provider	30 Jul 2019	• Information about IXP, network infrastructure, submarine cable and telecommunications market in Myanmar was shared. • Private operators' opinion about the difficulty of securing profitability on AP-IS projects for CLMV countries was confirmed.

4.4 Viet Nam

Agency	Sector	Date	Content
VNNIC	Government agency	15 Jan 2020	• VNNIC is operating the VNIX, an IXP, and has three nodes (Da Nang, Ha Noi and Ho Chi Minh) deployed in each region to keep domestic traffic local. Although the three nodes are currently not interconnected, there is a plan to do so. • VNIX only connects domestic traffic. International networks are connected through VNPT and Viettel. • More than 80 ISPs are operating in Viet Nam, and VNIX currently has 21 ISP members. Bandwidth continues to increase. Monthly circuit cost is around USD700-800 per Gbps.
NetNam	ISP	16 Jan 2020	• Most large ISPs in Viet Nam (9-10) have installed PoPs in Hong Kong and Singapore for international traffic services. • Content providers such as Facebook and Google are installing and servicing cache servers in Ha Noi. There is a Tier 3 IDC invested by NTT.

			• The lack of interoperability among CLMV countries makes it difficult to secure profitability. There is a need to proceed with public sector projects.
CMI	Telecommunications provider	17 Jan 2020	• There is a terrestrial network connecting South-East Asia, which is also the backbone network that spreads from China to Viet Nam through neighbouring countries. • Terrestrial routes are using CLMV countries' submarine cables as backup and primary communication paths for connections with Hong Kong.
CMC	Telecommunications provider, ISP	17 Jan 2020	• As the third largest wired telecommunications provider, the company is promoting broadband, ISP and IDC businesses, and operates a 2,500km terrestrial network and two international PoPs in Singapore and Hong Kong. • International Internet service is being provided directly through VNIX. It is difficult to expand business under the influence of companies such as VNPT and Viettel. • There will be resistance from operators in establishing a neutral IXP.

5. Submarine Cable Networks

There are two international gateways in Cambodia, three in Myanmar and five in Viet Nam (Table 3).

In Cambodia, there are two submarine cable systems landing in Sihanoukville for the Malaysia-Cambodia-Thailand (MCT) and the Asia-Africa Europe 1 (AAE-1) cable systems. The Mittapheap Cable Landing Station, operated by Telcotech since 2017, is the landing station for MCT, and the Sihanoukville Cable Landing Station, operated by CFOCN since 2017, is the landing station for AAE-1.

Myanmar was first connected to the South-East Asia–Middle East–Western Europe–3 (SEA-ME-WE3) submarine cable with a landing station in Pyapon in 2011. Subsequently in 2016, Myanmar was connected to the AAE-1 and SEA-ME-WE5 with the landing station in Ngwe Saung. Myanmar Posts and Telecommunications, the incumbent telecom operator in Myanmar, is the landing party in Myanmar for the SEA-ME-WE3 and SEA-ME-WE5 cable systems. China Unicom is the landing party in Myanmar for the AAE-1 cable system. In addition, SIGMAR, a 2,200km submarine cable construction linking Myanmar (Thanlyin) and Singapore (Tuas) was scheduled to be ready for service in 2020.

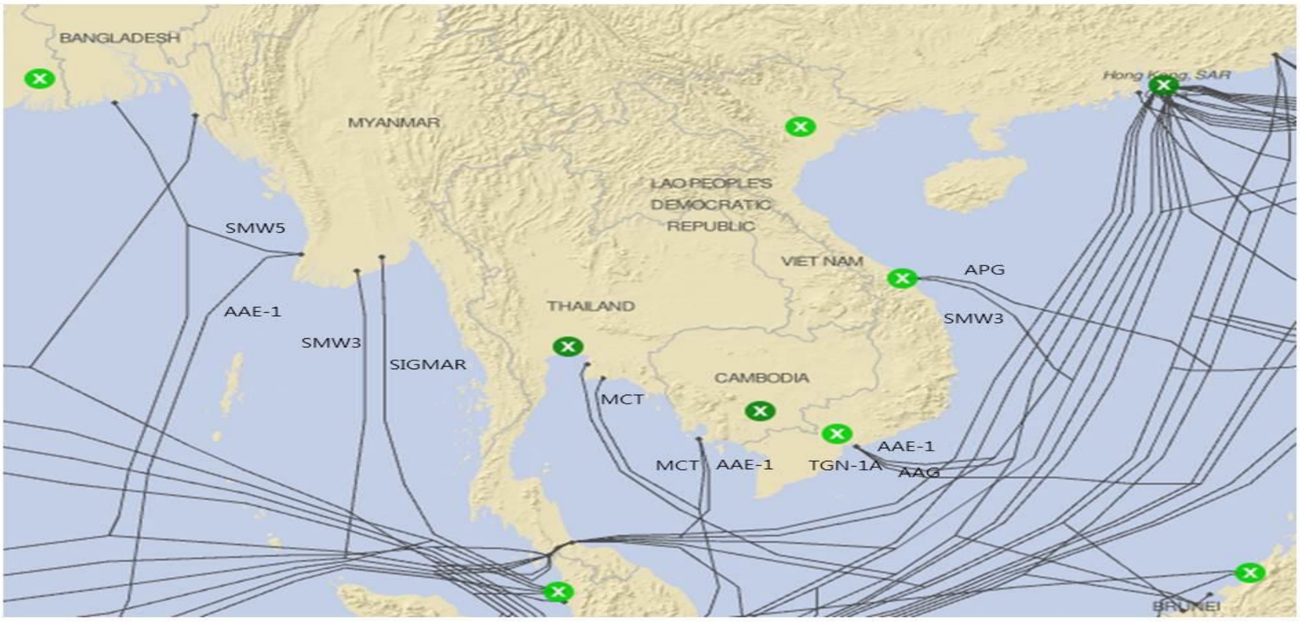
Viet Nam has five cable landing stations – two in Da Nang for SEA-ME-WE3 and the Asia-Pacific Gateway (APG), and three in Vung Tau for AAE-1, Tata TGN-Intra Asia and Asia-America Gateway (AAG). VNPT and Viettel are the dominant international submarine cable operators in Viet Nam.

Table 3: Submarine cable networks by country

Country	Cable name	Service commencement	Landing station	Holding capacity	Operator
Cambodia	MCT	2017	Sihanoukville	1.5T	EZECOM Telcotech
	AAE-1	2016	Sihanoukville	40T	HyalRoute
Myanmar	SEA-ME-WE3	2011	Pyapon	50T	Myanmar Posts and Telecommunications
	AAE-1	2016	Ngwe Saung	40T	China Unicom
	SIGMAR	2020	Thanlyin	2T	Campana
Viet Nam	SEA-ME-WE3	1999	Da Nang	960G	VNPT
	APG	2016	Da Nang	200G	VNPT
	AAE-1	2016	Vung Tau	2T	VNPT/Viettel
	TGN-Intra Asia	2009	Vung Tau	50T	Tata
	AAG	2011	Vung Tau	245G	VNPT

Source: Created by authors based on ITU map and newspaper articles in each country.

Figure 3: Submarine cable networks in CLMV countries

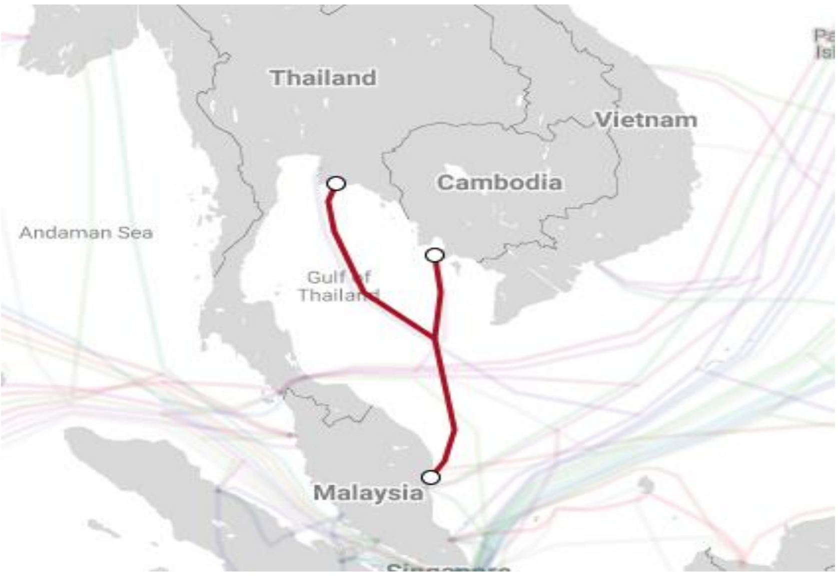


Source: ITU Interactive Transmission Map. Available at https://www.itu.int/itu-d/tnd-map-public.

5.1 MCT Cable

The MCT submarine cable system is a joint venture of Telcotech (a subsidiary of EZECOM) in Cambodia, Telekom Malaysia Berhad in Malaysia and Symphony Communication Public Company Limited in Thailand. The cable system consists of three pairs of fibre-optic cables that span 1,300km and has a capacity of at least 30Tbps. The MCT lands at Sihanoukville in Cambodia, Cherating in Malaysia and Rayong in Thailand, connecting the three countries.

Figure 4: MCT submarine cable diagram



Source: Submarine Cable Map, "Malaysia-Cambodia-Thailand (MCT) Cable". Available at https://www.submarinecablemap.com/#/submarine-cable/malaysia-cambodia-thailand-mct-cable.

5.2 SIGMAR Cable

The SIGMAR submarine cable system has a total length of 2,200km, consisting of four pairs of fibre-optic cables designed to connect the Thanlyin (Myanmar) International Gateway facility 16km South-East of Yangon to Tuas in Singapore.

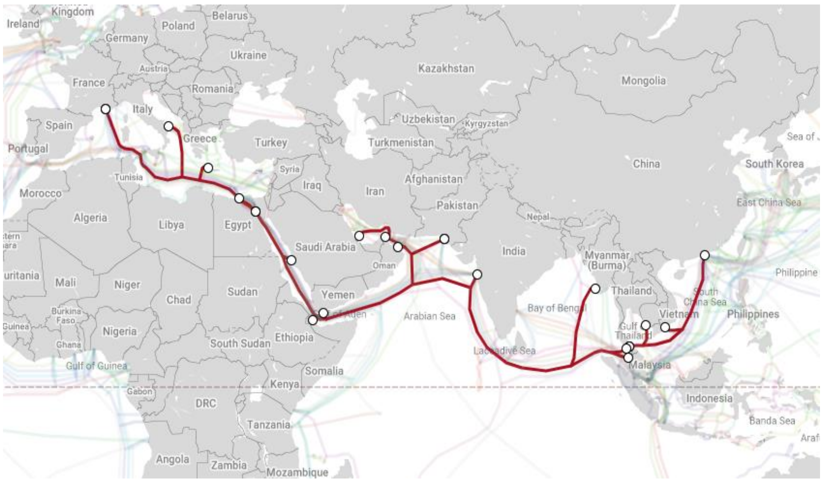
Figure 5: SIGMAR submarine cable diagram

Source: Submarine Cable Map, "Singapore-Myanmar (SIGMAR)". Available at https://www.submarinecablemap.com/#/submarine-cable/singapore-myanmar-sigmar.

5.3 AAE-1 Cable

The AAE-1 is a 25,000km submarine cable owned by 19 global service providers that connects South-East Asia with Africa and Europe. It connects Hong Kong, Viet Nam, Cambodia, Malaysia, Singapore, Thailand, Myanmar, India, Pakistan, Oman, United Arab Emirates, Qatar, Yemen, Djibouti, Saudi Arabia, Egypt, Greece, Italy and France. Powered by 100Gbps transmission technology, AAE-1 has the minimum capacity of 40Tbps.

Figure 6: AAE-1 submarine cable diagram



Source: Submarine Cable Map, "Asia Africa Europe-1 (AAE-1)". Available at https://www.submarinecablemap.com/#/submarine-cable/asia-africa-europe-1-aae-1.

5.4 SEA-ME-WE3 Cable

The SEA-ME-WE3 is the longest submarine cable in the world with a total length of 39,000km, linking 39 cable stations in 33 countries. Led by France Telecom and China Telecom and managed by Singapore's Singtel, the cable system was completed at the end of 2000. With continuous capacity expansion, it now has a capacity of 4.6Tbps.

Figure 7: SEA-ME-WE3 submarine cable diagram

Source: Submarine Cable Map, "SeaMeWe-3". Available at https://www.submarinecablemap.com/#/submarine-cable/seamewe-3.

6. Terrestrial Cable Networks[6]

In addition to submarine cables, there are a number of cross-border terrestrial cable networks in CLMV countries.

In Cambodia, three wired telecommunications providers (Telecom Cambodia, Camintel and Viettel) have 26,411km of backbone network. Cambodia's international Internet bandwidth is 57Gbps, and the terrestrial backbone network that is rapidly expanding includes the Cambodia–Viet Nam–Hong Kong route and the Cambodia–Thailand–Malaysia–Singapore route.

In Lao PDR, Lao Telecom has an international capacity of 5.7Gbps, and STL and ETL have terrestrial networks of 2.6Gbps and 2.4Gbps, respectively. Lao PDR’s international Internet gateway is via Viet Nam's Vung Tao–Yangyang submarine cable. Additionally, Lao PDR and China have agreed to deploy fibre-optic cables along the railroad in 2022 to connect Vientiane, Lao PDR with Kunming, China.

Myanmar's international Internet capacity is estimated to be 88Gbps as of 2017. The Myanmar-based Yangon–Muse–China Ruili route and Yangon–Keng Tung–China Daluo route are formed with Chinese providers. Other terrestrial networks include the Myanmar–Bangladesh–India route, Myanmar–Thailand route and Myanmar–Laos PDR route.

Viet Nam has terrestrial networks with capacities of 40Gbps to Lao PDR, 45Gbps to Cambodia and 140Gbps to China. Viet Nam's carrier providers, the Viet Nam Posts and Telecommunications Group (VNPT) and Viettel, have a 360Gbps North-South Optical Cable Network along the highway.

Figure 8: CLMV national terrestrial network diagram

Source: ITU Interactive Transmission Map. Available at https://www.itu.int/itu-d/tnd-map-public.

The CLMV countries have a total of around 300 backbone nodes and 11.72Tbps of terrestrial cross-border capacity with China, bilaterally connecting CLMV ISPs with telecommunications providers in China and Hong Kong. Tables 4 and 5 summarize the status of terrestrial networks in CLMV countries based on the survey and interviews conducted, with more details provided in Appendix 2.

6 This section is drawn from: ESCAP, “In-Depth Study of the Asia-Pacific Information Superhighway in CLMV Countries”, AP-IS Working Paper Series, March 2020. Available at https://www.unescap.org/resources/depth-study-asia-pacific-information-superhighway-clmv-countries.

Table 4: Status of inter-country terrestrial networks in CLMV countries

Division	Path	Connection city	Reference
1	Viet Nam ↔ Cambodia	Bavet, Chreythom	CMC Telecom
2	Viet Nam ↔ Lao PDR	Dasaban (Lao PDR), Lao Bao	ITU map
3	Cambodia ↔ Lao PDR	Veunkham (Lao PDR)	ITU map
4	Lao PDR ↔ Myanmar	Xieng Kok	ITU map
5	Cambodia ↔ Myanmar	Poipet (Cambodia), Bangkok, Waw Lay (Myanmar)	ITU map

Source: ITU Interactive Transmission Map. Available at https://www.itu.int/itu-d/tnd-map-public.

Table 5: Status of terrestrial networks between CLMV countries, China and Hong Kong

Division	Path	Connection city	Reference
1	Viet Nam ↔ Hong Kong Cable 1	Ha Noi, Chai Wan	China Telecom
2	Viet Nam ↔ Hong Kong Cable 2	Ho Chi Minh, Ha Noi, Chai Wan	China Telecom
3	Cambodia ↔ Viet Nam ↔ Hong Kong Cable	Phnom Penh, Ha Noi, Chai Wan	China Telecom
4	Lao PDR ↔ Hong Kong Cable	Vientiane, Chai Wan	China Telecom
5	Myanmar ↔ Hong Kong Cable	Ruili, Chai Wan	China Telecom
6	Singapore ↔ Thailand Cable	Singapore, Bangkok	China Telecom

Source: China Telecom, "Greater Mekong Transmission Solution".

7. Internet Traffic Management in CLMV Countries

An analysis of Internet traffic flows in CLMV countries in the 2020 ESCAP-NIA study[7] shows the need for improvement in Internet traffic management to minimize the tromboning effect and enable domestic Internet traffic to be exchanged and routed locally, thereby reducing costs and network delays, and increasing content upload speeds.

The severity of the tromboning effect is illustrated in Table 6, which is represented by the T value. The T value is obtained by dividing the routing distance of the packet along the traffic path between CLMV countries with the geographical distance between the countries. For example, the packet route from Cambodia to Thailand was found to be five times longer than the geographical distance. The higher the T value, the more severe the tromboning effect.

Table 6: Measurement of tromboning in CLMV countries

	Cambodia	Lao PDR	Myanmar	Viet Nam	Thailand
Cambodia	-	32	7	2	5
Lao PDR	11	-	33	4	3
Myanmar	6	3	-	2	6
Viet Nam	28	2	23	-	3

Source: ESCAP, "In-Depth Study of the Asia-Pacific Information Superhighway in CLMV Countries", AP-IS Working Paper Series, March 2020, p. 37. Available at https://www.unescap.org/resources/depth-study-asia-pacific-information-superhighway-clmv-countries.

The high T value between Cambodia and Lao PDR, and between Lao PDR and Myanmar, which exceeds 30 requires urgent attention. The high T value between Viet Nam and Cambodia and Viet Nam and Myanmar, which exceeds 20 also needs to be noted.

According to the providers interviewed by the research team, there were many complaints about the speed and quality of wired and wireless telecommunications. Despite direct routes established between Lao PDR and Myanmar, it was found that actual traffic was being sent through other countries. Similarly, although Cambodia and Viet Nam are neighbouring countries, traffic was being transmitted via the United States and China.

Generally, the T values show significant room for improvement in the management of Internet traffic in CLMV countries. Although most CLMV countries are physically interlinked with fibre-optic cables, actual traffic flows through inefficient routes. To optimize traffic flows and improve service quality, the active involvement of governments and regulatory agencies in addressing the tromboning effect is urgently required.

[7] ESCAP, "In-Depth Study of the Asia-Pacific Information Superhighway in CLMV Countries", AP-IS Working Paper Series, March 2020. Available at https://www.unescap.org/resources/depth-study-asia-pacific-information-superhighway-clmv-countries.

8. IXP Status

As of the end of 2019, there is at least one IXP in each of the CLMV countries (Table 7). Although not registered in PeeringDB, the Lao National Internet Center (LANIC) confirmed that an IXP was launched in 2010 with seven ISPs members. Despite the presence of IXPs in these countries, many ISPs continue to have their own peering and transit policies with other service providers.

Table 7: IXP status in CLMV countries

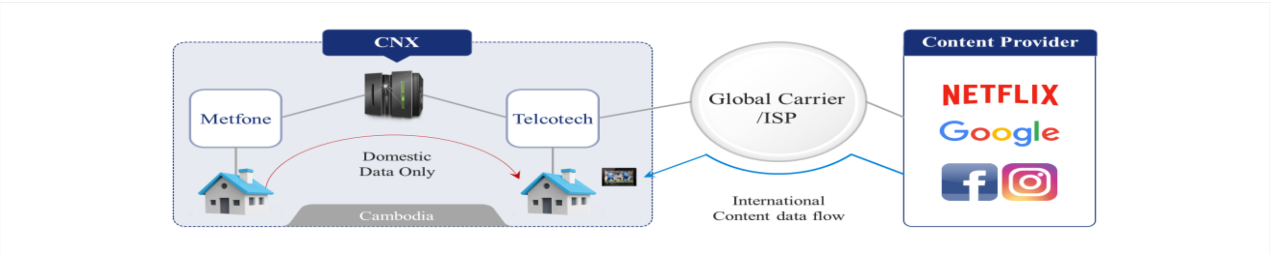
Country	IXP	Operating institution	Number of ISPs connected	Total connection capacity (Gbps)
Cambodia	CNX	Sabay Digital	36	125
	TC DIX	Telecom Cambodia	34	25
Lao PDR	LANIX	LANIC	7	49
Myanmar	MMIX	Ministry of Transport and Communications	13	59
Viet Nam	VNIX-DN	VNNIC	2	2
	VNIX-HCM	VNNIC	18	158
	VNIC-HN	VNNIC	14	127

Sources: PeeringDB. Available at https://www.peeringdb.com/ and interview with LANIC.

8.1 Cambodia

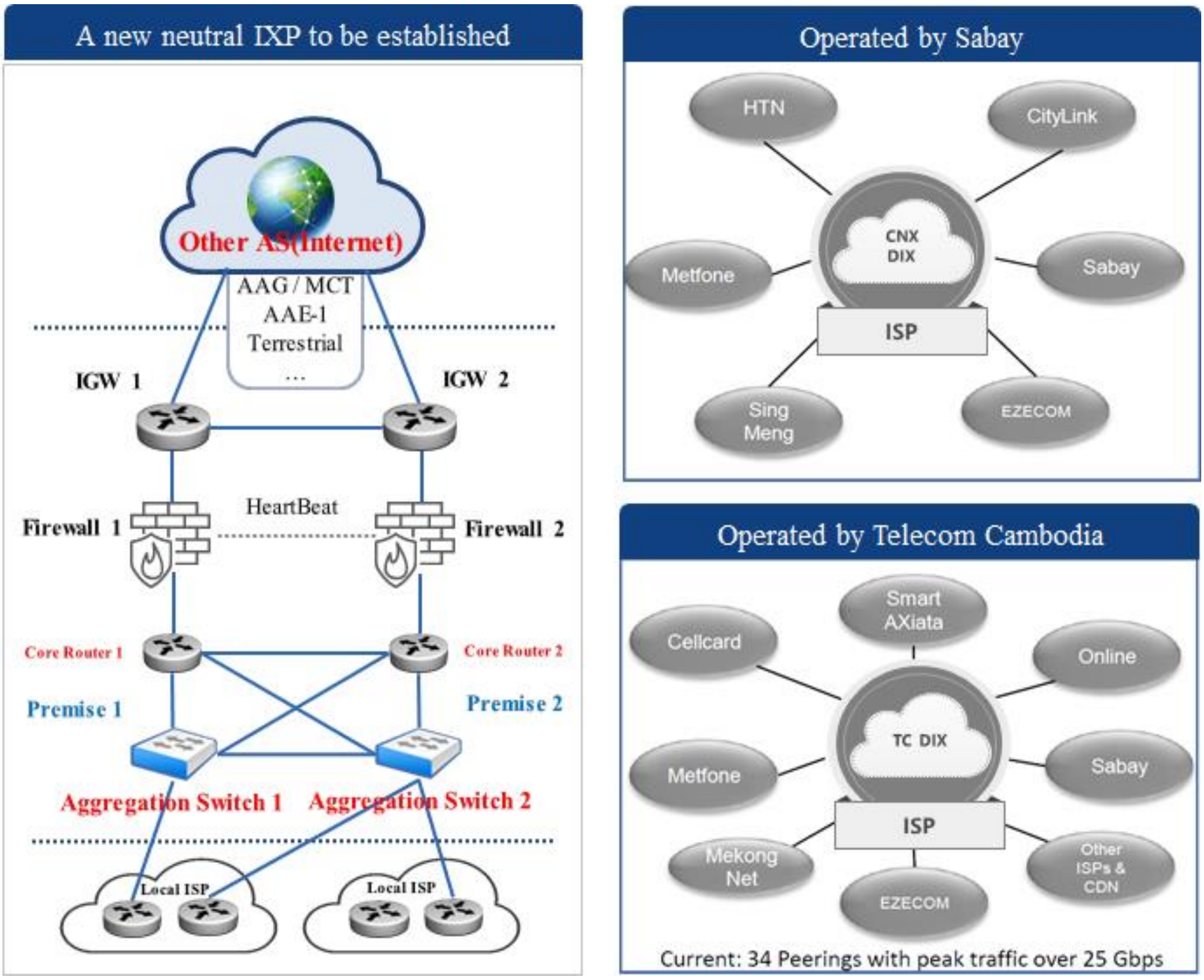
There are two IXPs in Cambodia – Cambodia Network Exchange (CNX) operated by Sabay Digital (Cambodia's leading mobile gaming company), and TC DIX operated by Telecom Cambodia. CNX was established in 2008 and is located in Phnom Penh with 36 ISP members. However, the demand for global content takes up a large portion of total traffic, and ISPs have to directly connect with global ISPs and content providers to fulfil domestic demands in Cambodia.

Figure 9: Cambodia IXP configuration



Cambodia has plans to establish a new neutral IXP with links to international gateways and terrestrial networks. Together, the three IXPs can ensure more efficient traffic exchange and provide users with more stable network services (Figure 10).

Figure 10: Planned IXP configuration in Cambodia

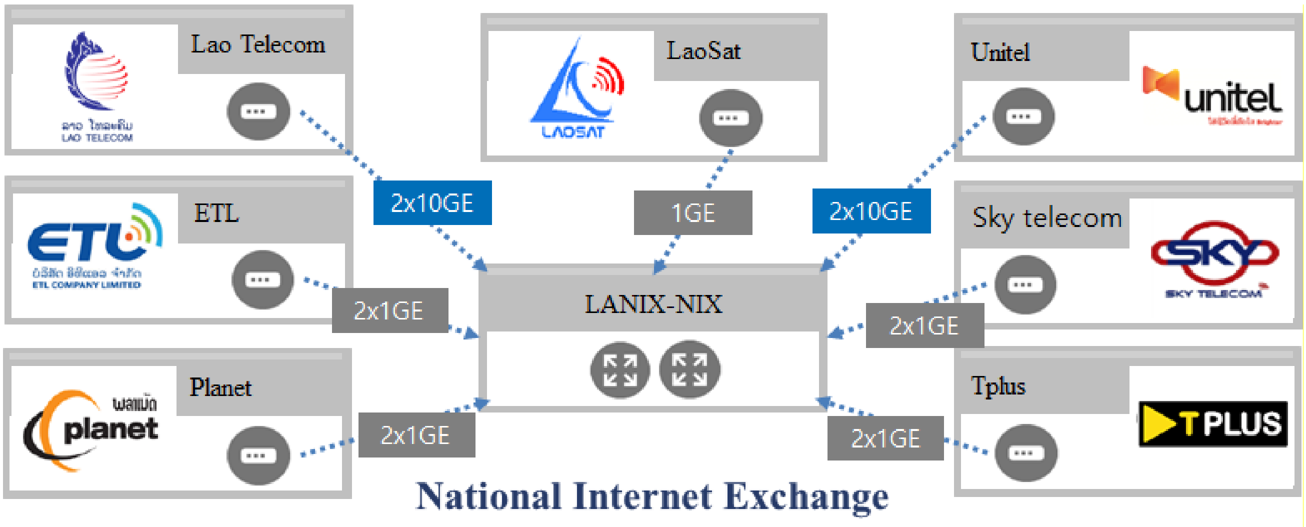


Source: Department of Telecommunication Regulation, Telecommunication Regulator of Cambodia.

8.2 Lao PDR

LANIC was established in 2010 as an organization within the Ministry of Post and Telecommunications to manage the .la country code top-level domain. In accordance with the National Socio-Economic Development Plan to advance socioeconomic development and transform Lao PDR from a landlocked country into a land-linked country, LANIX was established, which currently has seven members. However, it is unclear whether the international Internet transit service provider is hosted at LANIX.

Figure 11: Lao PDR IXP configuration



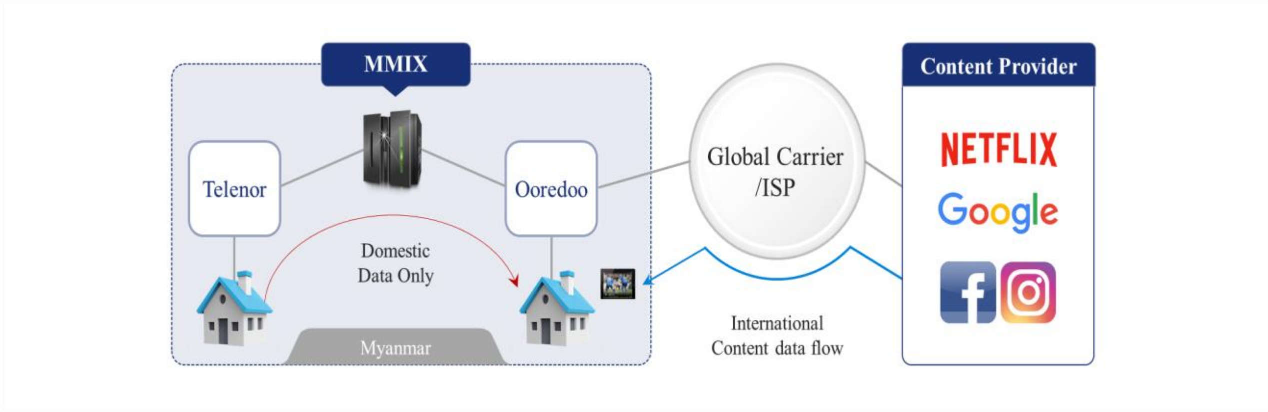
Source: Saysomvang Souvannvong, Soulisack Phommansan and Chatouphol Phoumin, LANIC, Ministry of Posts and Telecommunications, 9 July 2020.

LANIX's total connection capacity is 49Gbps, which is smaller than the other three countries. All network connections except LaoSat have duplex structure with 10Gbps or 1Gbps bandwidth to ensure stability and reliability. In 2017, Lao Telecom joined the Bangkok Neutral Internet Exchange as a 10Gbps member to minimize the high fees they pay to global transit providers, China Telecom, CAT Telecom (Thailand), VNPT and Viettel.

8.3 Myanmar

In Myanmar, the first IXP – Myanmar Internet Exchange (MMIX) – was established in 2017. MMIX is a government-owned subsidiary and provides peering service to 18 member ISPs. MMIX is located at the True IDC in the Myanmar ICT Park in Yangon. The IDC acts as a peering hub in an environment that is secure and can support 24/7 access, which is an advantage. However, according to interviews with key informants in Myanmar, network operators and content providers in Myanmar lack awareness of the benefits of connecting to an IXP, and continue to deliver content through direct connection with international content providers. In this context, a Peering Forum was organized in 2019 to promote the roles and benefits of MMIX and attract members. With the aim to facilitate cooperation with global content service providers and international businesses, and attract investment from them, the Government of Myanmar established the National Internet Exchange Department under the Ministry of Transport and Communications as part of its endeavour to build a digital economy through IXPs.

Figure 12: Myanmar IXP configuration

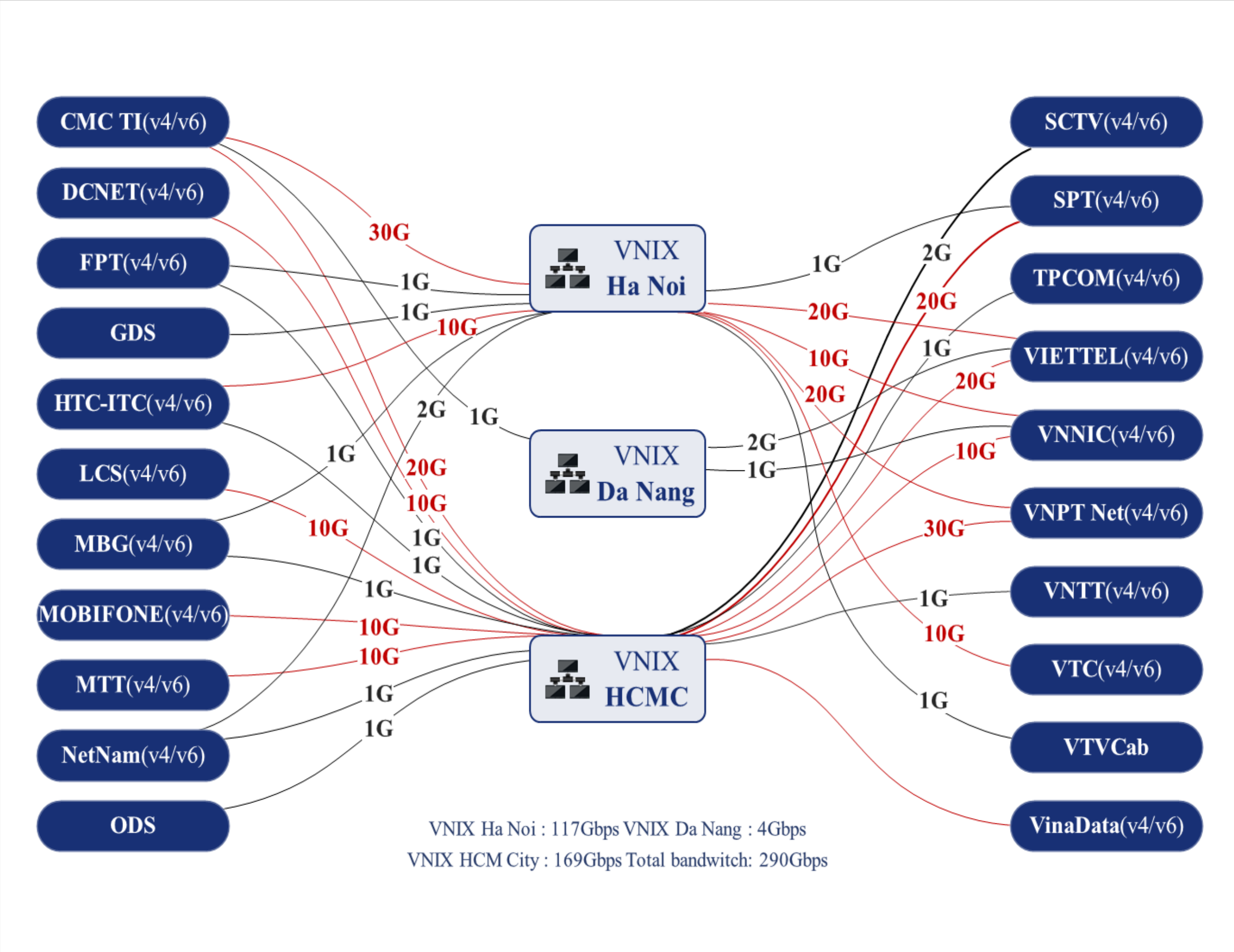


8.4 Viet Nam

The Viet Nam National Internet Exchange (VNIX),[8] established in April 2000, is an internal system of the Viet Nam Internet Network Information Center (VNNIC), which performs domain name and Internet Protocol (IP) management, assignment, supervision and Internet traffic exchange functions under the Ministry of Information and Communications. VNIX plays an important role in the development of the Internet in Viet Nam, such as connecting ISPs and institutions, reducing Internet transmission costs, improving network quality and securing the Internet infrastructure. VNIX has three nodes in the three regions of Viet Nam: North (Ha Noi), South (Ho Chi Minh) and Central (Da Nang), but they operate independently and there are no connections between them. VNIX has two types of connection – N x 1Gbps/port and N x 10Gbps/port. Currently, it has 21 members and each ISP member is connected to one or more nodes of the VNIX (Figure 13).

[8] VNNIC, "About VNIX System". Available at https://vnnic.vn/en/dns-vnix/about-vnix-system.

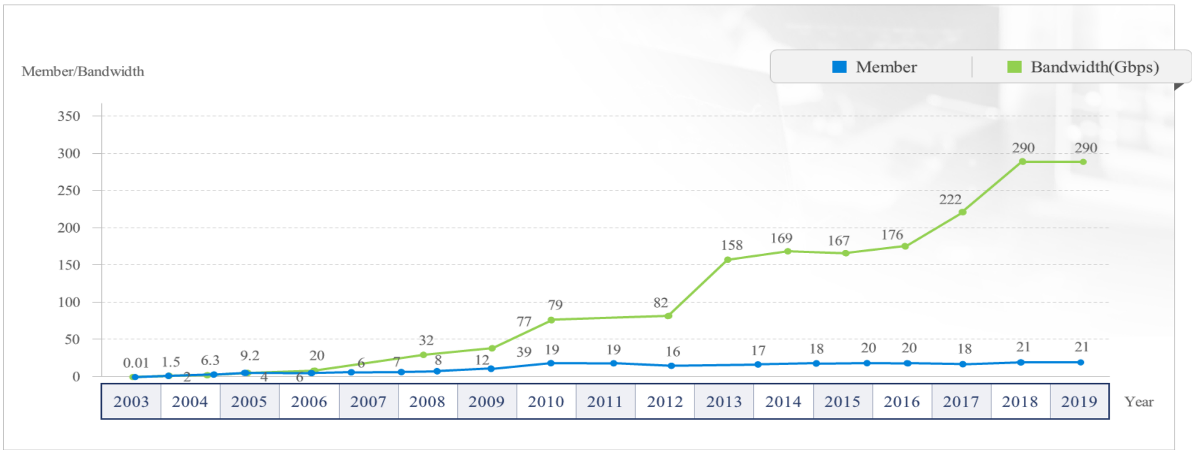
Figure 13: Viet Nam IXP configuration



Source: VNNIC, "About VNIX System". Available at https://vnnic.vn/en/dns-vnix/about-vnix-system.

Since the establishment of VNIX, the number of member ISPs and bandwidth have been increasing every year as shown in Figure 14.

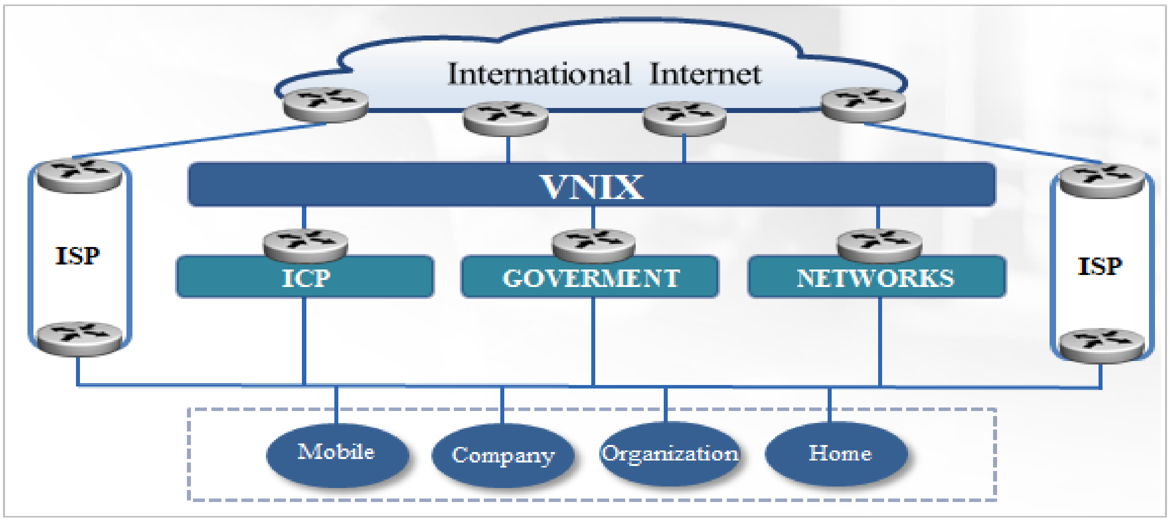
Figure 14: Number of VNIX members and bandwidth growth



Source: VNNIC "Report on Viet Nam Internet Resource 2019", 2019.

Catering for international traffic and providing interconnections between international content providers, government agencies, networks and ISPs, VNIX plays an important role in Viet Nam's Internet ecosystem (Figure 15). VNIX enhances the efficiency of ISP connections, which translates to lower cost, faster delivery of content and better quality of services for the end users.

Figure 15: Viet Nam's Internet ecosystem



9. Case Studies

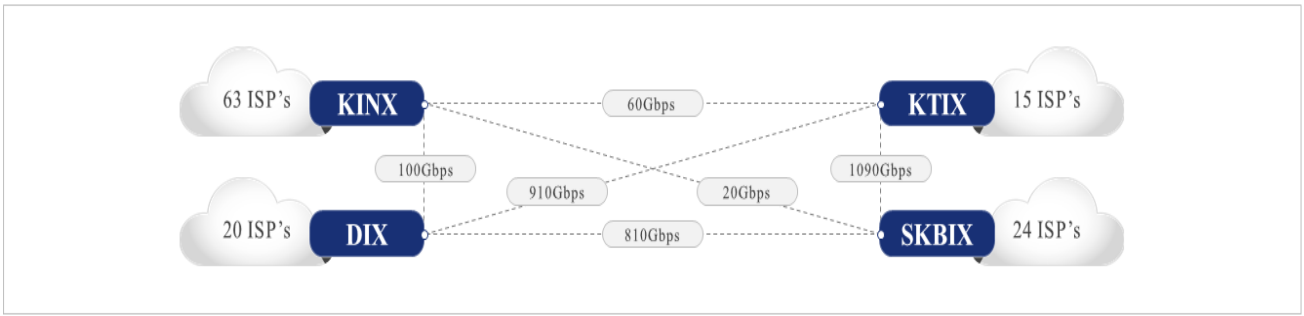
9.1 Case Study of IXPs in the Republic of Korea

In the Republic of Korea, there are four IXPs in operation:

1. KTIX, operated by KT, interconnects 15 ISPs and the three other IXPs.
2. DIX, operated by LG U+, interconnects 20 ISPs and the three other IXPs.
3. SKBIX, operated by SK Broadband, interconnects 24 ISPs and the three other IXPs.
4. KINX, a neutral IXP, interconnects 63 ISPs and the three other IXPs.

The four IXPs are interconnected with high speed fibre-optic links, which means for new ISPs, by simply becoming a member of one IXP, they can take advantage of the peering and transit arrangements in all four IXPs. The Korean IXP model demonstrates an effective Internet exchange environment for ISPs to interconnect with each other to provide users with fast, affordable services. The Government of the Republic of Korea has provided guidelines for the interconnection market to rule out unilateral terms and conditions by major ISPs and encourage fair contract conditions.

Figure 16: Interconnection structure of IXPs in the Republic of Korea (as of June 2018)



Source: Korea Internet and Security Agency (KISA), "Korea Internet White Paper 2018", 2019. Available at https://www.kisa.or.kr/public/library/etc_View.jsp?regno=0011974.

Table 8: Linkage status of IXPs (as of June 2018)

IXP	Operating institution	Number of ISPs connected	Total connection capacity (Gbps)
KTIX	KT	15	840
DIX	LG U+	20	2,900
KINX	KINX	63	1,786
SKBIX	SK Broadband	24	1,571

Source: KISA, "Korea Internet White Paper 2018", 2019. Available at https://www.kisa.or.kr/public/library/etc_View.jsp?regno=0011974.

KTIX has the largest backbone network in the Republic of Korea with a dual-node configuration. Its total connection capacity is 840Gbps linking three IXPs and 15 ISPs (Table 9). In 2017, KTIX started Internet Protocol version 6 (IPv6) traffic exchange with DIX and SKBIX.

Table 9: KTIX linkage status (as of June 2018)

	Linkage status
Linkage method	Point of switch, Ethernet
IXP linkage	DIX (910G), SKBIX (1,090G), KINX (60G)
ISP linkage	840G linkage of 15 providers including: SK Telecom (240G), LG U+ (120G), Sejong Telecom (110G), T-broad (120G), Dreamline (40G), Samsung SDS (20G), LG Hello Vision (40G), Hyundai HCN (80G), Information Integration (20G)

Source: KISA, "Korea Internet White Paper 2018", 2019. Available at https://www.kisa.or.kr/public/library/etc_View.jsp?regno=0011974.

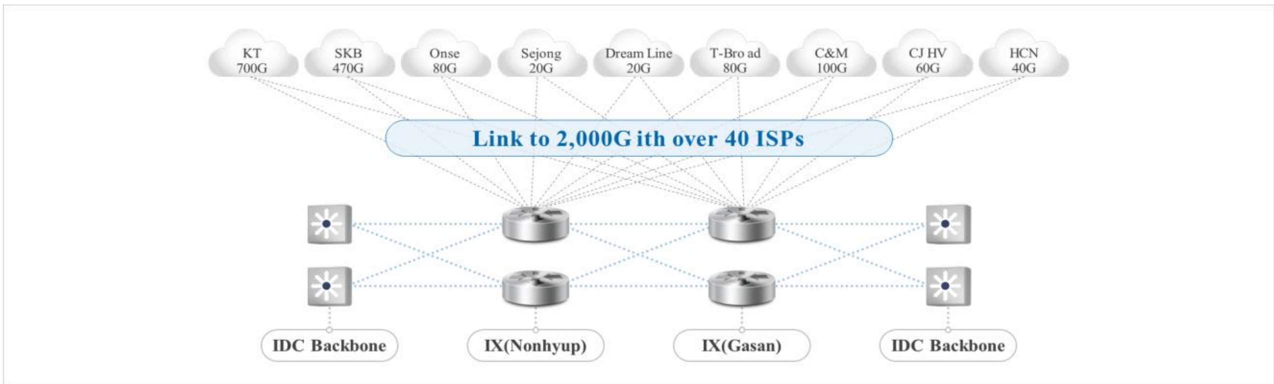
DIX, operated by LG U+, has a dual-node configuration that is geometrically separated. KDIC, the largest IDC in the Republic of Korea, and DIX are co-located at the same node. Currently, DIX interconnects around 20 ISPs and has a capacity of 2,900Gbps (Table 10).

Table 10: DIX linkage status (as of June 2018)

	Linkage status
Linkage method	Point of switch, Ethernet
IXP linkage	KTIX (1,150G), SKBIX (810G)
ISP linkage	2900G linkage of 20 providers including: SK Telecom (160G), Sejong Telecom (100G), Dreamline (120G), D'Live (140G), Hyundai HCN (60G), LG HelloVision (100G), T-broad (60G)

Source: KISA, "Korea Internet White Paper 2018", 2019. Available at https://www.kisa.or.kr/public/library/etc_View.jsp?regno=0011974.

Figure 17: LG U+ domestic Internet network integration status



Source: created by LG U+.

SKBIX exchanges domestic Internet traffic through two IXPs and 24 ISPs, and its link capacity is 1,571Gbps. It provides services such as the Internet, VoIP and IP television by establishing redundancy and bypass routes between nodes across the country.

Table 11: SKBIX linkage status (as of June 2018)

	Linkage status
Linkage method	Point of switch, Ethernet
IXP linkage	KTIX (1,090G), DIX (810G)
ISP linkage	1,517G linkage of 24 providers including: Dreamline (20G), Sejong Telecom (50G), SK Telecom (680G), CJ (160G), Hyundai HCN (60G), T-broad (220G) and CMB (26G)

Source: KISA, "Korea Internet White Paper 2018", 2019. Available at https://www.kisa.or.kr/public/library/etc_View.jsp?regno=0011974.

KINX provides bilateral and multilateral peering services using an L2 switch and route server. Peering policy is determined by a voluntary agreement between members. Currently, it provides IPv6 L2 peering service in a dual-stack environment. The total linkage bandwidth is 1,786Gbps and is connected using 100GE, 10GE, GE and FE interfaces. KINX interconnects 63 ISPs and content providers, including global content providers such as Amazon Web Services, Apple, Google and Microsoft, giving them space and network connectivity to set up local content servers.

Table 12: KINX linkage status (as of June 2018)

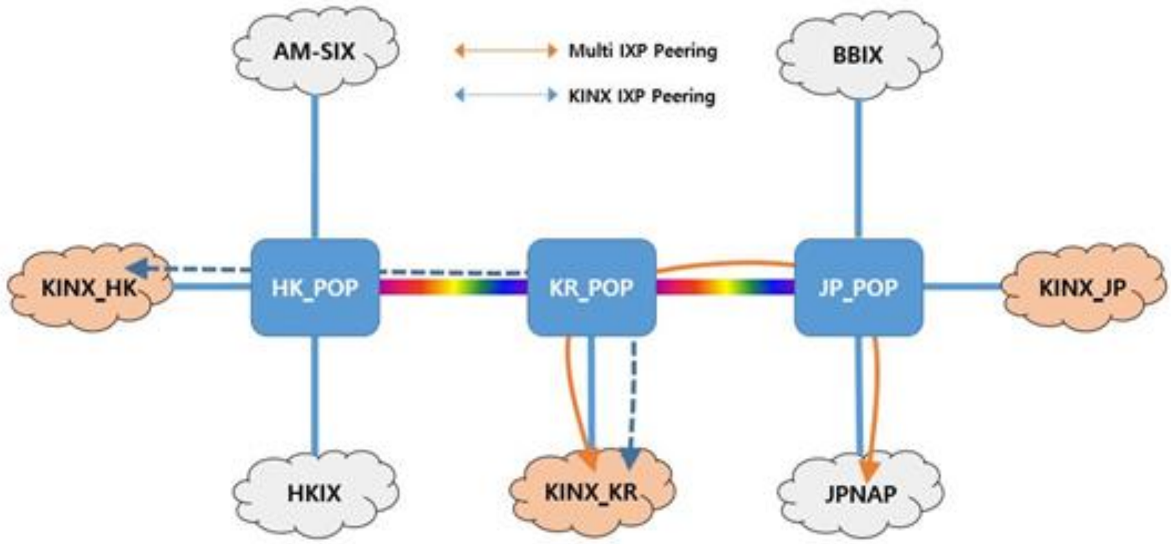
	Linkage status
Linkage method	BGP v4 ~ BGP+
ISP linkage	1,786G linkage of 63 providers including: Samsung SDS (12G), NexG (1G), Dreamline (30G), Delivere (150G), Tvroad (150G), LGHV (60G), Beautiful Broadcast (12G), Hyundai HCN (50G), Kakao (40G) , CD Networks (40G), Naver (40G), Samsung Electronics (1G), KDDI Korea (1G), Government Integrated Computer Center (20G), Amazon (160G), Microsoft (20G), SoftLayer (80G), Apple (200G), Twitch (100G), Alibaba (40G) and Hurricane Electric (10G)

Source: KISA, "Korea Internet White Paper 2018", 2019. Available at https://www.kisa.or.kr/public/library/etc_View.jsp?regno=0011974.

KINX is the nation's first L2-based IXP. With the same network structure as other countries' IXPs like HKIX of Hong Kong, AMS-IX of the Netherlands and JPIX of Japan, it offers BGP peering between IXP members. Through KINX, major system operators, ISPs, content delivery networks, cloud service providers and government agencies are interconnected.

Figure 18 shows the KINX network diagram. It takes submarine cables on lease from international network operators to run PoPs in the Republic of Korea, Hong Kong and Japan. International PoPs can connect to the KINX IXP for direct peering with IXP members in the Republic of Korea. KINX signed IXP cooperation agreements with Japanese IXPs – BBIX and JPNAP – to build a structure for free peering between IXP members connected to either country's IXPs, and plans to pursue similar arrangements with HKIX (Hong Kong) and AMS-IX (Netherlands).

Figure 18: KINX network diagram



9.2 Case Study of IXPs in Kenya[9]

In 2012, only about 30 per cent of Kenya's traffic was localized. Today, however, nearly 70 per cent of traffic is localized due to the growth of the Kenya IXP (KIXP), which has multiple nodes in Nairobi and Mombasa. KIXP is operated by the Telecommunications Service Providers of Kenya, a non-profit organization representing the interests of ISPs and other telecommunications operators. KIXP was established in 2010 in anticipation of increased local and regional Internet traffic after the launch of submarine cables.

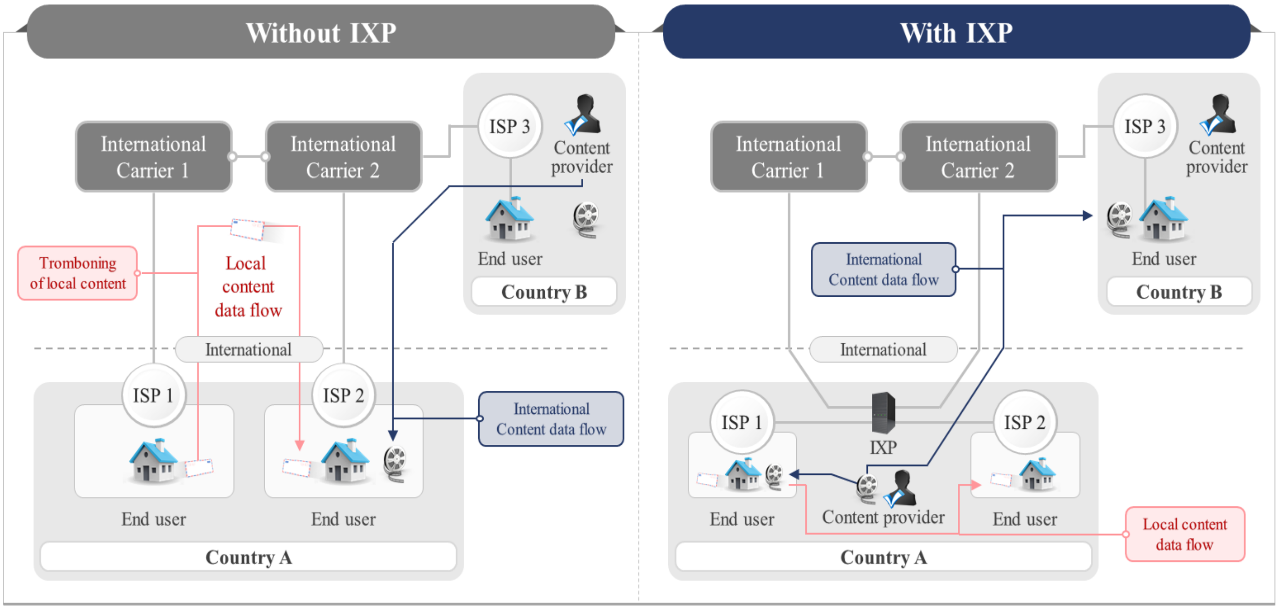
KIXP grew from 25 members carrying a peak traffic of 1Gbps in 2012 to 56 members with peak traffic of 19Gbps in 2020, and cost savings quadrupling to USD6 million per year. Latency reduced from 200-600ms in 2012 to 2-10ms in 2020.

KIXP transformed into multisite and multicity nodes, some of which are hosted in IDCs. KIXP dropped mandatory peering requirements to encourage new members to join, and as a result, global content providers such as, Akamai, Amazon Web Services, Cloudfare, Facebook, Google, Microsoft and Netflix, added PoPs and edge cache in the country.

Within the African region, KIXP and its hosting IDCs are appealing as a hub because they offer diverse submarine cable capacity landing in Mombasa, plus access to CDNs and other international content and services. Figure 19 and Table 13 summarizes the changes before and after installing an IXP.

[9] This subsection is drawn from: Michael Kende, "Anchoring the African Internet Ecosystem: Lessons from Kenya and Nigeria's Internet Exchange Point Growth", Internet Society, June 2020. Available at https://www.internetsociety.org/issues/ixps/ixpreport2020/; and Michael Kende and Charles Hurpy, "Assessment of the impact of Internet Exchange Points – empirical study of Kenya and Nigeria", Internet Society, April 2012. Available at https://www.internetsociety.org/resources/doc/ixpimpact.

Figure 19: Example of international connectivity (without IXP vs with IXP)



Source: Michael Kende and Charles Hurpy, "Assessment of the impact of Internet Exchange Points – empirical study of Kenya and Nigeria", Internet Society, April 2012. Available at https://www.internetsociety.org/resources/doc/ixpimpact.

Table 13: KIXP introduction effect analysis

Benefit	Without KIXP	With KIXP	Summary
Latency	200-600ms	2-10ms	Network performance improvement
Local traffic exchange	Not possible	19Gbps peak	Total USD1,440,000 annual savings in international traffic
Content	All content is linked via international lines, most of the content is overseas	Google localization, Expansion of content hosting	New mobile data traffic increases revenue up to USD6 million per 100Mbps
E-government	Tax collection by hand	Tax collection online	It depends on KIXP for transparent tax collection and income growth
Domain names	.com is the main domain for foreign registration	Register .ke as a key domain	KENIC uses KIXP to improve service delivery to .ke
Local traffic path	All local traffic passes through international lines	Exchange increasing regional traffic through KIXP	KIXP is more attractive to content providers and backbones that are accessible to local users

Source: Michael Kende and Charles Hurpy, "Assessment of the impact of Internet Exchange Points – empirical study of Kenya and Nigeria", Internet Society, April 2012. Available at https://www.internetsociety.org/resources/doc/ixpimpact.

9.3 Summary of Case Studies

The case studies show the benefits of establishing IXPs, which can be summarized as follows:

- **Reduce latency** – ISP can reduce transmission latency by reducing tromboning, which is especially important for time-sensitive services such as VoIP and interactive applications.
- **Increase cost savings** – Domestic traffic exchange through the IXP can lower domestic and international traffic costs for ISPs, and this cost reduction is likely to be passed on to end users. In the Republic of Korea, for example, if the ISP has a contract and link with one of the four IXPs, it does not have to pay transit fee to send domestic traffic to the international IXP, and does not have to pay fees to return the traffic back to the home network.
- **Build resiliency** – IXPs contribute to greater network resilience as the network does not have to rely on international submarine cables or satellite systems for local traffic exchange. Thus, it is essential for CLMV countries to establish a robust and reliable IXP and an interconnected IXP backup system to enhance the overall resilience of their ICT infrastructure.
- **Improve content delivery** – When international content is hosted locally, this increases cost savings and lowers latency in accessing content. Local content developers hosting their content locally can also benefit from lower latency. The decreased latency in accessing content increases the usage of that content, which in turn increases the revenues of ISPs that sell data packages.
- **Develop the local Internet ecosystem** – IXPs can attract a range of local and international operators, which can trigger innovation, investment, and business and job opportunities. In addition, interconnected IXPs can enhance access to e-government services thereby increasing the usage.

10. An IXP Model for CLMV Countries

This section proposes an IXP model for CLMV countries based on the findings from primary and secondary research conducted. This proposed IXP model aims to enhance connectivity in the CLMV countries and achieve the goals of the AP-IS initiative.

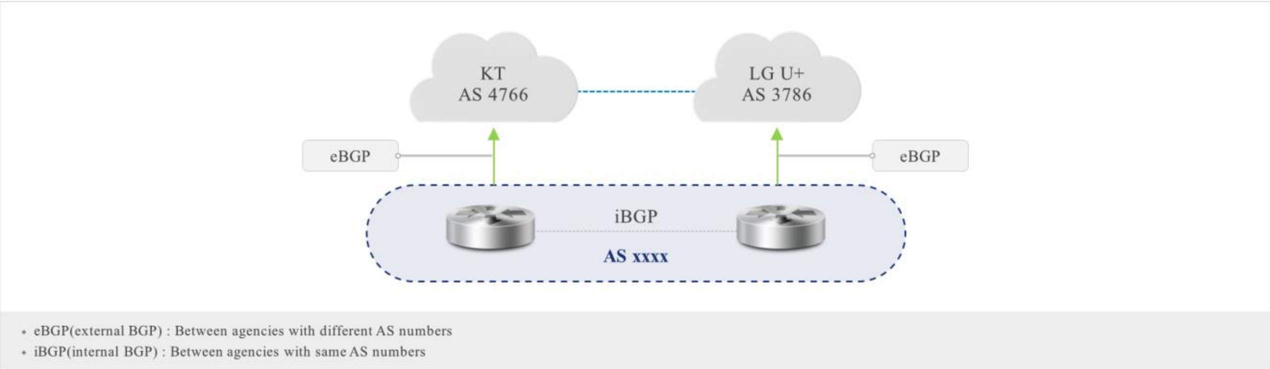
10.1 Internet Traffic Management Cooperation

Cooperation among CLMV countries will be important to develop and harmonize Internet traffic management policies and practices, including technical network configuration and routing standards, in an open, neutral and non-discriminatory manner. As part of CLMV cooperation in establishing IXPs, technical capacity building and knowledge sharing in the efficient management of Internet traffic will also be important.

The BGP algorithm can be used to find the best routing path. BGP is a protocol that enables two organizations using different routing policies to communicate by exchanging their network information. In general, BGP brings the following advantages:

- Prevent service isolation in the event of a single ISP line failure.
- Provide a bypass route for equipment or line failure at specific links.
- Automatic switching and restoration of traffic through BGP linkage.
- Adjust traffic between ISPs using various BGP attributes.
- Adjust route configuration according to customers' desired policy.
- Apply filters for inbound or outbound traffic.
- Implement dual configuration without changing the IP address.

Figure 20: BGP routing protocol configuration



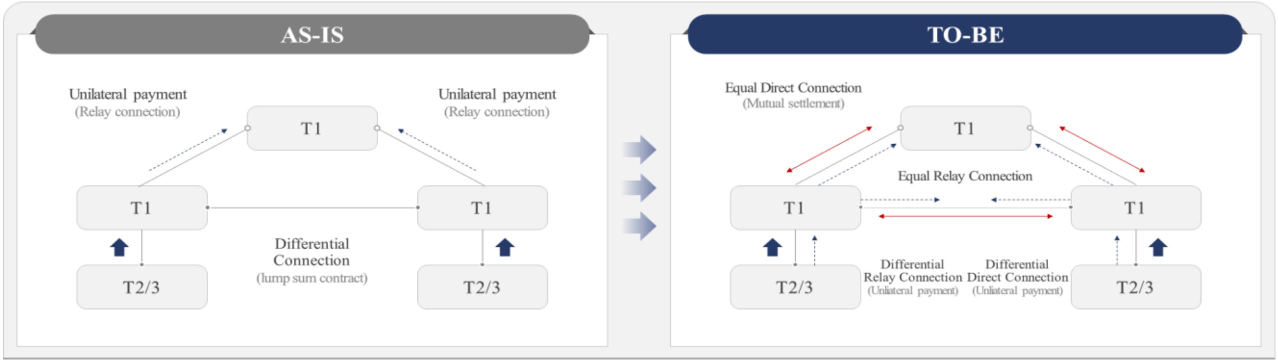
Source: Created by LG U+.

Figure 20 shows the use of BGP in the Republic of Korea. BGP requires mutual agreement to connect border routers to exchange traffic between different autonomous systems. The internal BGP or iBGP is used for router traffic within the same autonomous system, while the external BGP or eBGP is used for traffic between different autonomous systems.

Governments in CLMV countries play a key role in enabling the development of IXPs and removing barriers to their growth and success. They include promoting interconnection via policy and regulatory frameworks, and encouraging competitive access to wired and wireless connections.

For example, to connect to the global Internet, an ISP's autonomous system must be connected to the autonomous system of one or more other ISPs that are already connected to a global transit provider. As illustrated in Figure 21, all Internet traffic between small ISPs (T2 and T3) must pass through the upstream provider's network. Commonly, interconnection between the same tier is free, but sometimes incumbent players impose unilateral payment charges. Hence, the Government of the Republic of Korea developed and applied a mutual cost settlement method to rationalize the cost of traffic usage in 2016 to promote fair interconnection.

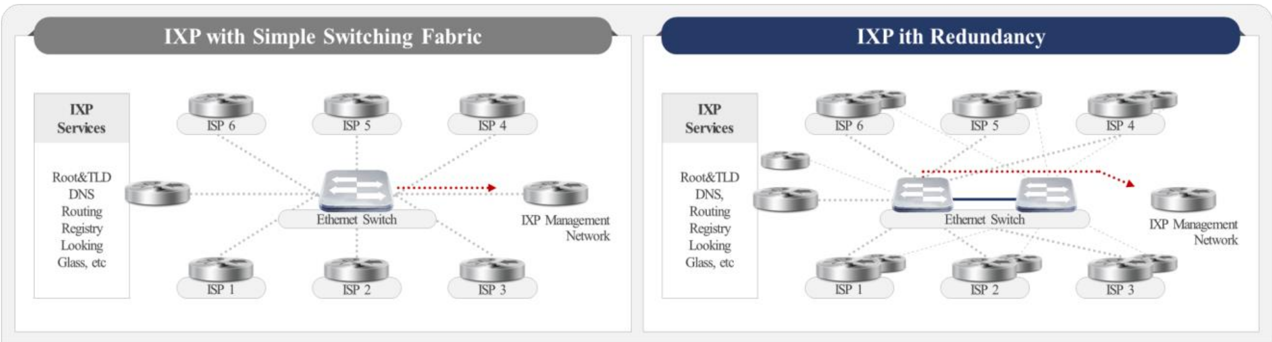
Figure 21: IXP interconnection settlement



Source: Created by LG U+.

Building network resilience is one of the goals of the AP-IS. Cooperation to improve the resilience of IXPs include establishing more IXPs, system dualization and network link diversity with primary/reserve circuit installation. Multiple route options are particularly vital during emergency situations to improve the availability of services and enable swift response.

Figure 22: Building IXP resilience with redundancy



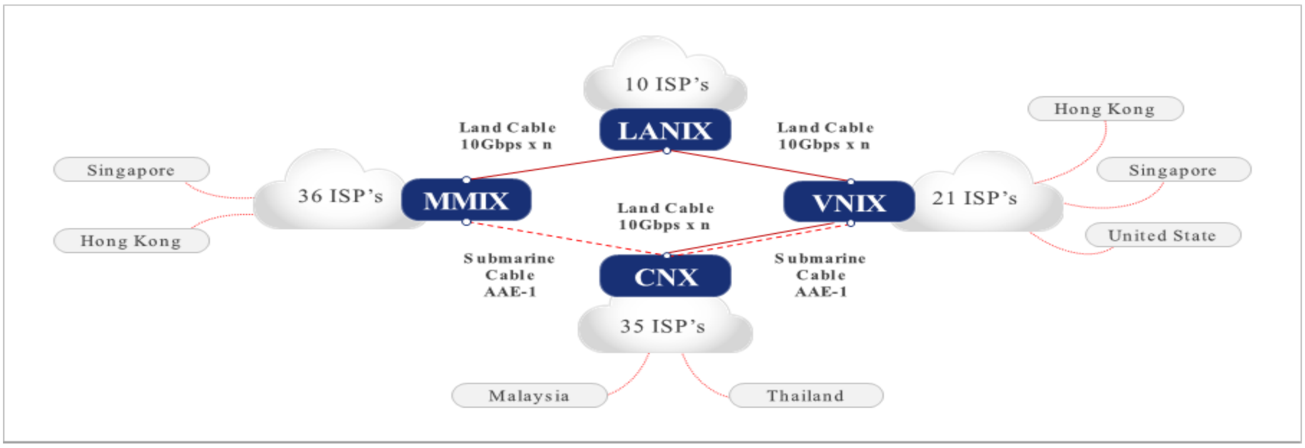
Source: Philip Smith, "ISP and IXP Design", presentation made at APNIC 34, August 2012. Available at https://conference.apnic.net/34/pdf/apnic34-ispixp-networkdesign_1346077403.pdf.

To enhance connectivity, new IXPs should be established at the place of network crossing where they can take advantage of access to existing network operators' infrastructure, and ISPs should be allowed to freely link to the IXP and exchange traffic with each other.

The network topology, or the physical or logical arrangement of network elements, needs to be agreed among stakeholders in CLMV countries. A hybrid topology is recommended for overall stability and for the availability of alternative path in case of disruption. Further, if possible, a geometrically separated path is recommended.

Network capacity among IXPs should be designed to fulfil traffic demands by forecasting mid- to long-term needs. The traffic growth rate (up to 50 per cent year-over-year growth) needs to be considered in the design of the network capacity. There should be less dependence on submarine cables. Terrestrial cables should be used for 50 per cent of the traffic, and submarine cables should be used for the other 50 per cent.

Figure 23: A ring-type inter-country IXP network typology



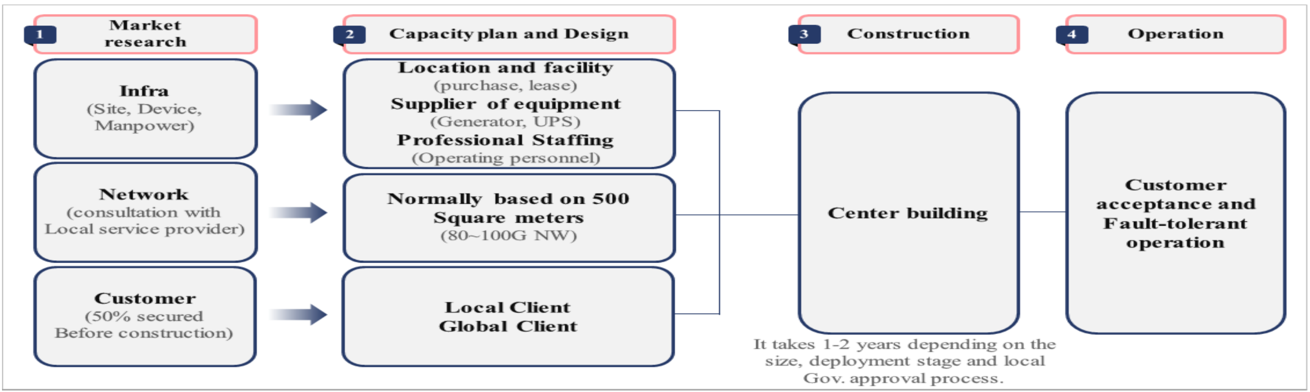
As Figure 23 shows, the following are recommended for the IXP model in CLMV countries:

- Deploy a ring-type inter-country IXP network topology, rather than a full-mesh type, to reduce latency and network costs for inter-country traffic.
- Connect IXPs to primary and redundant trunk lines in 10G increments. Fibre-optic networks of telecommunications providers in four countries are connected bilaterally at the border junction. The Myanmar–Cambodia link can be made with submarine cables (AAE-1), while the Cambodia–Viet Nam link can be made with terrestrial and submarine cables (AAE-1). The Lao PDR–Myanmar and Lao PDR–Viet Nam links can be made with terrestrial cables.
- Deploy a neutral IXP in the capital city and major cities of the country where major carriers' main backbone networks meet. This will encourage global Internet transit service providers, ISPs and content providers to set up PoPs in CLMV countries.
- Establish an IXP hub for CLMV countries. Cambodia, Myanmar and Viet Nam have submarine cable landing stations, which are sufficient for an IXP hub. As shown in Figure 23, Cambodia can serve as a gateway to Malaysia and Thailand through the submarine cable landing station. Myanmar with three submarine cable landing stations can serve as a gateway to India, Bangladesh and Europe. Viet Nam with two submarine cable landing stations can serve as a gateway to Hong Kong and North Asia.
- Deploy an interconnected IXP system of CLMV + Thailand since it is adjacent to all CLMV countries, is connected by land, has good accessibility, and is geographically centrally located. This will enhance resilience by diversifying traffic routes and strengthening cooperation.

10.1 Building and Operating IDC with IXP

If a country decides to establish two or more neutral IXPs, building a neutral IDC with the IXPs is suggested to enhance connectivity. It will also help enhance the resilience of the network to natural calamities such as fire and flood, force majeure events such as blackouts, and security issues. This set up will enable local service hosting and local content development and applications. It can also promote in-house capability to operate critical Internet infrastructure, traffic management and security measures. In establishing a new IDC with IXP as a key infrastructure of the Internet ecosystem, a stepwise approach (Figure 24) is important to secure robustness, sustainability and scalability in long-term operation.

Figure 24: Stepwise approach to build IDC with IXP



Factors to consider before building a new IDC include:

- Availability – Redundancy of power and communication lines.
- Safety – Separation between the computer room and office, premium seismic design and automatic fire extinguishing system.
- Security – At three levels: external, doorway and computer/server room.
- Scalability – Extra capacity for additional demands.
- Efficiency – High-efficiency power supply, air conditioning equipment with automatic equipment management system and facility management system.

Table 14: Prior considerations for establishing an IDC

Availability	• Plan for redundancy of infrastructure • Isolation from the outside (space/energy) • Computer room plan for constant temperature and humidity • Watertight facility plan to prevent leakage in computer room
Safety	• Construction to meet computer load facility conditions • Structural diagnosis and reinforcement plan • Confirmation of structural stability of computer room and usability against vibration of floor structure

	• Optimization plan for evacuation in case of fire, and fire prevention plan to prevent spread of fire
Security	• Establishment of security system to reduce risk of damage to key facilities and information leakage • Architectural security system plan for each stage: traffic, access restriction and access control zone • Securing dedicated space and enhanced physical security
Scalability	• Securing computer room and space for future expansion • Sufficient variable expansion space within the security zone • Reasonable flexible plan to cope with irregular server expansion
Efficiency	• Plan to minimize management route • Space division and integrated plan for optimized environment construction by function • Plan considering the utilization and adaptability of existing building facilities • Operation room composition and break room construction considering operators' work efficiency

Fundamentally, the IDC should comply with international standards. Regarding the size of the IDC, a 1,500m^2 is recommended considering future IDC and PoP demands. Figure 25 shows an example of an IDC floor plan. The following are some guidelines for calculating the general floor space, and the number of racks and equipment required:

- Calculation for system room area – Typically, the system room area is 70-80 per cent of the total area required.

- Calculation for the number of racks – The racks are calculated by arranging the system indoor racks squarely and taking into account the equipment layout and the access floor width (60cm x 60cm) of the system room on a 19-inch basis.

- Arrangement of equipment – The equipment should be arranged in one column and the gap between columns should be 1-1.5m of operator space in consideration of heating, ventilation and air conditioning (HVAC) and the operating environment, e.g., to open front and rear doors of the equipment. Generally, racks are arranged at intervals of 2.5-3m. The number of rack devices required can be calculated by estimating the maximum power, data capacity and number of ports for each rack. The uninterruptible power supply (UPS) and batteries should be placed in separate sections with separate finishing, and it is recommended that they should not be placed in the same area as the white space in the server room.

Figure 25: IDC floor plan

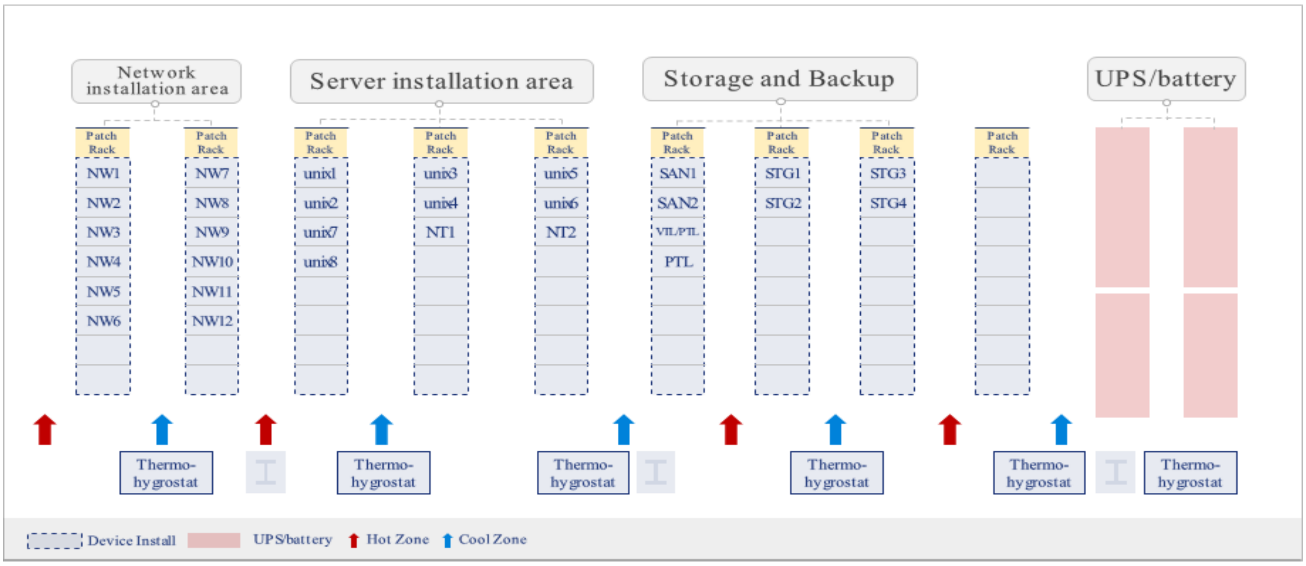


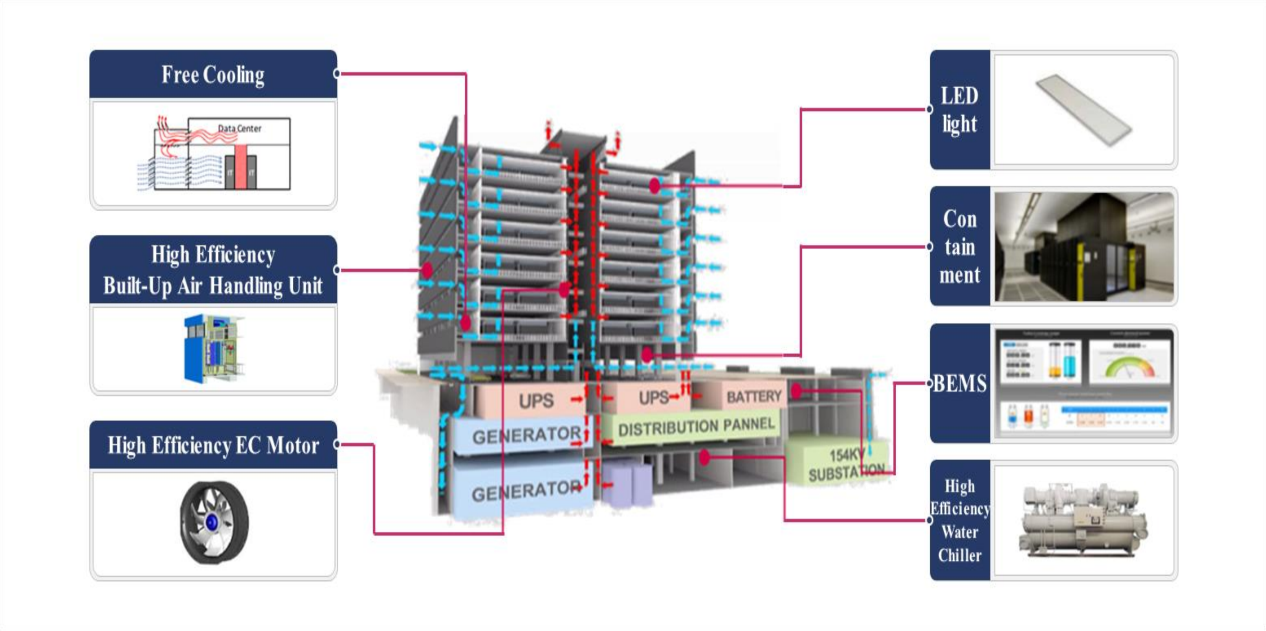
Table 15 provides an example of calculating the required rack unit (RU), assuming that one rack in the IDC can accommodate standard 42 RUs. The example shows that the network requires a total of 162 RUs. Adding 50 per cent of free space, the total required number of RUs is 324RUs (162 RUs x 2). Dividing it by 42 RUs, the standard rack size, the required number of racks is eight. Adding storage and server racks, the estimated number of racks required is 12 in total.

Table 15: An example of rack quantity calculation

Division		RU required per equipment 1RU free space between devices included	Number of Device	Total RU		50% more space	The number of Racks required (42RU standard)	
Network & Security	Router	6	6	36	162	324	8 (324/42 = about 7.7)	12 racks Requird (42RU standard)
	Backbone Switch	10	6	60				
	Distribution Switch	3	4	12				
	Access Switch	2	6	12				
	L4 Switch	3	2	6				
	FireWall	3	4	12				
	Web Firewall	3	2	6				
	QoS	3	2	6				
	IPS	3	4	12				
Storage	Account	Standard 1 Rack					1	
Server	Account (AP&DB)	Standard 1 Rack					1	
	Information (DB)	Standard 1 Rack					1	
	Integration Server	Standard 1 Rack					1	
At Least 12 racks of space must be secured								

Figure 26 shows the main equipment required for IDC construction, which include cooling systems, LED lighting, high-efficiency built-up air handling unit, containment, building energy management system or BEMS, high-efficiency electronically commutated or EC motor, high-efficiency water chiller, and UPS, batteries and on-site emergency generators, as well as the network infrastructure and servers.

Figure 26: Components of IDC construction

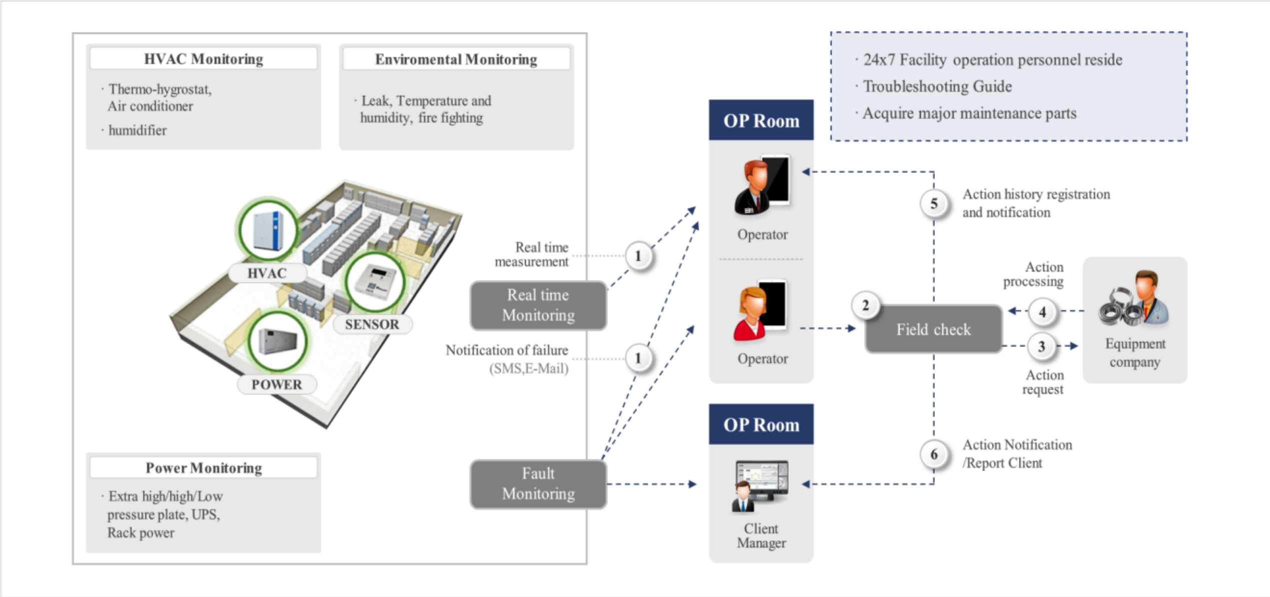


Typical IDC operations include environmental monitoring, air conditioning monitoring and power monitoring. The IDC can be divided into network, electrical, mechanical and security parts. According to the size of the IDC, the staff of each part is composed of operating personnel available on a 24x7x365 basis. Periodic preliminary inspections of building, network, electricity, air conditioning, firefighting and security facilities are essential to ensure faultless operation and performance of the IDC. Measures to address technical problems such as power failure must be pre-established to minimize damages.

Figure 27 shows a simulation diagram for monitoring the main facilities of the IDC in real time through the facility management system. The process flow of the system involves: real-time monitoring and failure occurrence notification → on-site confirmation → action tips → action processing → registration and notification of action details → notice of action/customer report.

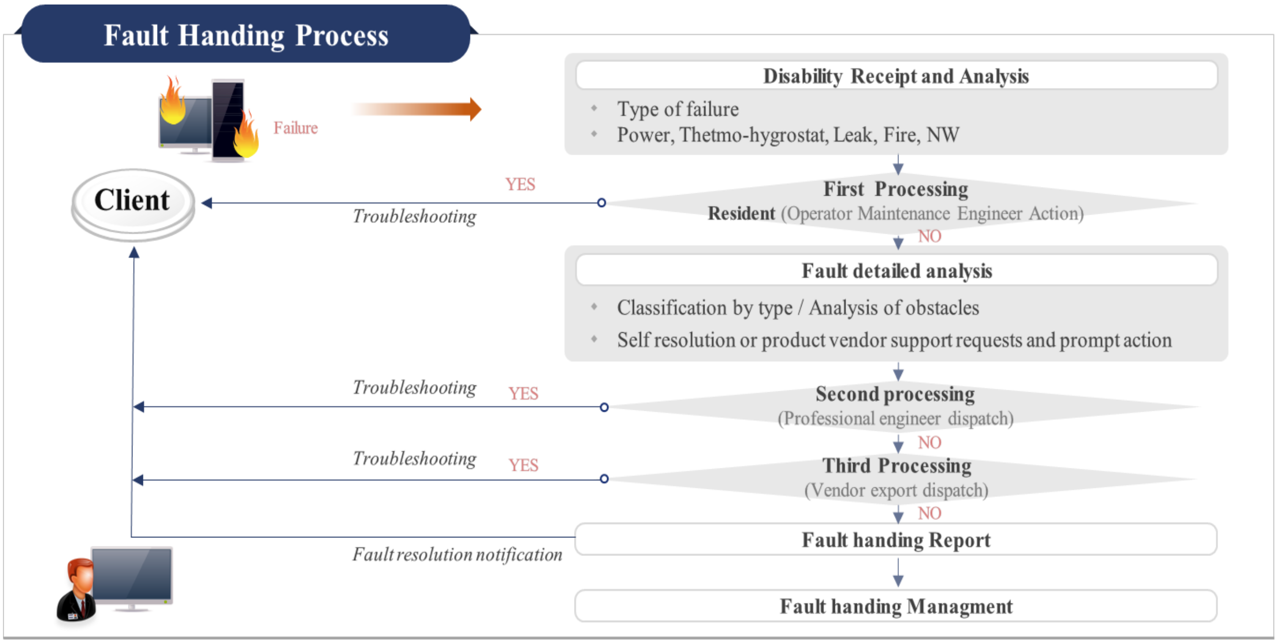
During the real-time monitoring of each facility, once a failure is detected, the operator is immediately notified by SMS or email, then, through site verification, the operator can discuss the immediate action that can be taken to address the failure with the relevant facility provider.

Figure 27: IDC operating system



The facility management system can also process the fault handling and notification to corresponding clients. Based on operators' analysis of the fault, it will be processed accordingly, which may involve maintenance work carried out by the operator, or the dispatch of engineers and equipment suppliers (Figure 28).

Figure 28: Fault handling system



10.2 Funding Model and Estimated Cost

There are various models for funding the establishment of IXPs, but this paper outlines the five most common models, as follows:

1. **Project financing or special-purpose corporation model** – A special-purpose corporation is established for the project.

When several companies join together to participate in a project, this model is preferred.

- Strength: The responsibility and performance of the funds are limited to the special-purpose corporation.
- Weakness: The cost of financing is higher than that of providing collaterals because it attracts funds to projects with uncertain business feasibility, and business delays may occur depending on the interests of the participants. It requires continuous follow-ups to manage the established corporation.

2. **Consortium model** – A form of joint participation by dividing the scope or role of the project, either by zone or by task (technology and capital).
   - Strength: Distribution of responsibilities and risks among the participants.
   - Weakness: The distribution of profits among the participants leads to a decrease of profit, takes a lot of time to collaborate, and in the case of joint work, disputes related to the division of responsibility can occur.

3. **Build, operate and transfer** – A provider raises funds, completes construction and then takes charge of the operation for a certain period. This model is used when a project's profit is stably guaranteed to recover long-term investments.
   - Strength: This model can encourage public financial institutions' participation in the project. Risks arising from the project can be appropriately distributed among the project implementer, donor and contractor.
   - Weakness: Negotiations, risk allocation and borrowing between project participants take a lot of time, and there are many risks borne by lenders, resulting in high financial costs.

4. **Donor financing** – Funds are requested from multilateral development banks with government guarantees to raise project expenses at low interest. Funds can be raised through the Asian Development Bank, Asian Infrastructure Investment Bank and the World Bank.
   - Strength: Low-interest loans with a longer grant period and low commercial interest rate.
   - Weakness: Due to the complicated process, it takes a long time to attract funds. Payment guarantees of the beneficiary country and the process of securing 15 per cent of the initial project cost are needed.

5. **Vendor financing** – A financial technique in which a company purchases equipment or services after borrowing funds from equipment suppliers.
   - Strength: Procurement of the necessary equipment at a low cost can reduce financial burden.
   - Weakness: Reliance on the equipment supplier and it can be difficult to apply to a complex (building + equipment + service) project.

For the establishment of IDC with IXP in CLMV countries, this study recommends the donor financing model. The establishment of IDC with IXP requires a relatively large amount of investment, as well as multinational collaboration with telecommunications providers. International banks such as the Asian Development Bank, Asian Infrastructure Investment Bank and the World Bank are suited to handle multilateral issues and raise funds for individual government agencies.

Table 16 provides the estimated cost for the establishment of a typical IDC with IXP. The cost of building construction for a new IDC is estimated to be USD18,650,000, the annual leasing cost of one access link between four IXPs is USD1,356,000, and the annual in-house cross-connection cost is USD200 per core. The estimated total cost for the construction of the IDC facility is USD20 million. This amount does not include operational expense and transit cost.

Table 16: Itemized capital expenditures

Section	Item	Cost(USD)
Building	• Basement, Ground Floor, 1500m²	4,000,000
	Sub Total	**4,000,000**
Internal Construction	• Tray	200,000
	• Electrical	200,000
	• Power	650,000
	• Interior	200,000
	• Server room, Constant Temperature and Humidity Equipment	3,000,000
	• Temperature and humidity measurement system	50,000
	Sub Total	**4,300,000**
Power	• Generator	1,500,000
	• UPS, Battery	2,000,000
	• Automatic control system(FMS)	400,000
	• Server Room Distribution Board	130,000
	• Power receive and distribution facility	300,000
	• Power measurement system	250,000
	• Grounding facility	50,000
	Sub Total	**4,630,000**
Fire	• Leak detection	40,000
	• Fire extinguishing equipment	700,000
	• Access Floor	100,000
	• Security equipment (Access control)	250,000
	• Floor load construction	200,000
	Sub Total	**1,290,000**
Network, Security	• Backbone Router	600,000
	• Backbone Switch	1,200,000
	• Workgroup Switch	400,000
	• Firewall	500,000
	• Optical cable construction	500,000
	Sub Total	3,200,000
Management System	• Network Monitoring	300,000
	• Server Monitoring	150,000
	• Hazardous Traffic Monitoring	150,000
	• Integrated monitoring system(DBMS)	300,000
	• OP room Interior	330,000
	Sub Total	**1,230,000**
Total		**18,650,000**

The estimated cost is based on an IDC with a Tier 3 IXP that is 1,500m² in size with a basement level, a ground level, 500 racks and a one-year construction period. Construction of the exterior building is calculated based on the standard in the Republic of Korea. Cambodian informants indicated that construction cost is significantly lower in Phnom Penh. Nonetheless, this is an estimated cost that excludes detailed design.

The internal construction process includes the following:

- Tray construction – Communication trays (for unshielded-twisted-pair and fibre-optic cables) and electric tray construction.
- UPS secondary power construction – A rack-to-rack construction at the distribution panel.
- Power construction – Thermo-hygrostat power supply, thermo-hygrostat distribution board, bus duct, UPS trunk, generator trunk, fire-fighting electric lamp, heating facility, vertical/horizontal wiring and redundant cables.
- Interior work – Zone clearance (zone interior cage, constant temperature and humidity chamber partition), door (automatic door, zone door) and floor epoxy waterproofing.
- Server room – Constant temperature and humidity system consisting of water-cooled constant temperature, humidity chamber, cold water coil, three-way valve, water pipe construction, cooling tower, automatic control construction, pump and expansion tank construction.

- Temperature and humidity measurement system – Temperature and humidity sensors, collectors and operating systems.

The electric work process includes the following:

- The self-generator – A diesel generator, accessories and installation work.
- UPS and batteries – A UPS system, UPS battery and rack installation.
- Automated control system – Customized hardware and software development.
- Water distribution facilities – External power input, high-voltage and low-voltage panel construction.
- The power measurement system – Power measurement equipment and operating system.
- Grounding facilities – Secure grounding, raised floor grounding, UPS room, floor server room ground terminal board and pipe improvement service.

Network- and security-related costs include cabling work to connect various network equipment (switch, router and firewall) in the IDC, as well as external network costs such as transmission for incoming line, interconnection installation cost, fibre-optic in-house wiring and network equipment. Management system-related costs include network and server monitoring, harmful traffic intrusion monitoring, integrated management and operation room interior.

The transmission network connecting the IXPs can be deployed in two ways. The first option is direct cable deployment,[10] and the other option is leasing existing communication links from carrier service providers with fibre-optic networks to the IXPs.

The construction of 100km of two-way duct with fibre-optic cable costs approximately USD2,000,000. In contrast, to lease 10G capacity, the annual cost for the carrier network is estimated to be an average of USD344,000 per link. In an IDC, tenants incur cost for in-house wiring (cross-connection) between different tiers and/or within the same tier. These costs are approximately USD200 per core, or higher if the IDC is multi-tiered.

Table 17: Transmission and network equipment price

Description	Non-recurring charge (USD)	Recurring charge (USD)	
		Monthly recurring charge	Annual cost
Transmission			
Optical transmission system cost, 100km, 10G, P2P	2,094,000		
Subtotal	2,094,000		
Lease, 10G, P2P ↔ Phnom Penh			
Ha Noi ↔ Phnom Penh		27,000	324,000
Phnom Penh ↔ Yangon		32,000	384,000
Yangon ↔ Vientiane		27,000	324,000
Vientiane ↔ Ha Noi		27,000	324,000
Subtotal			**1,356,000**

[10] Direct cable deployment is described in: ESCAP, “In-Depth Study of the Asia-Pacific Information Superhighway in CLMV Countries”, AP-IS Working Paper Series, March 2020. Available at https://www.unescap.org/resources/depth-study-asia-pacific-information-superhighway-clmv-countries.

Specifications and budgets could not be finalized due to the difficulty of calculating local price estimates. Once the exact demand and capacity of the actual IDC are confirmed, it is likely that the overall amount of investment will change.

Table 18: Calculation of total cost

Description	Unit price (USD)
IDC construction	18,600,000
Transmission link lease	1,356,000/year
Interconnection installation	200 x N core
Total	**19,956,200 + yearly transmission**

10.3 Way Forward

Broadband connectivity and Internet use in Asia and the Pacific have been growing rapidly over the last decade. Despite efforts to enhance connectivity, CLMV countries continue to lag behind in providing access to affordable broadband connection for users. The establishment of IXPs can bring positive impacts on the affordability, latency and traffic capacity in CLMV countries.

In this context, this working paper provides policy recommendation for enhancing Internet traffic exchange and management systems in CLMV countries, as contribution towards the achievement of AP-IS goals. More specifically, recommendations include the following:

- Deploy a ring-type inter-country IXP network topology and establish an IXP hub for CLMV countries to promote stable and resilient interconnection among CLMV countries, with neighbouring countries such as Thailand, and internationally, attracting global content providers and strengthening cooperation.
- Establish at least one neutral IXP in each country's capital city as the optimum location for ISPs and content providers to connect with the IXP. Relatedly, it is recommended that an IDC is established with an IXP to provide better hosting facility to providers. Based on best practices, there should be at least two IXPs in each CLMV country for their stable and competitive operations.
- Adopt the donor financing model to leverage funds from multilateral development banks in collaboration with government and other stakeholders. The estimated total cost of establishing an IDC with IXP is USD20 million.
- Cooperate among CLMV countries and with stakeholders in neighbouring countries like Thailand to harmonize national ICT policies and standards, and provide an enabling environment for enhancing Internet traffic exchange and management. Accordingly, set up a working group or task force of CLMV and interested neighbouring countries [11], in alignment with the AP-IS initiative, to agree on actions to be taken and facilitate the signing of a Memorandum of Understanding among CLMV and neighbouring countries.

Overall, these recommendations aim to improve Internet traffic and network management through the establishment of a network of IXPs, towards more affordable, resilient, high-quality

[11] ESCAP conducted consultation meeting with Ministry of Digital Economy and Society of Thailand in November 2020 and the Ministry agreed to participant to follow-up study to enhance connectivity in the region.

broadband access for all in CLMV countries. Recommendations of this working paper will be shared through various regional dialogue and platforms.

Appendix 1. Checklist for IDC Establishment

Section	Considerations	Direction of establishment	Remarks
Surrounding environment	Geographical location	Fire, noise and air pollution safety zones	
		Flood, earthquake, vibration damage safety zone	Minimum 100 yards away from flood-prone areas
	Centre exposure	External display board, guide plate installation principle	
	Independent composition of computer centre	Operation of infrastructure facilities dedicated to the computer centre	
		Spatial isolation composition and independent centre operation environment	
Building requirements	Seismic design	Reflection of building seismic rating	Earthquake Law Regulation
	Computer equipment room	Acceptance of all kinds of computer equipment	1,000 ㎏/m² ~1,200 ㎏/m²
	Infrastructure facility room	Acceptance of large infrastructure equipment	1,000 ㎏/m² ~ 1,200kg/m²
	Floor slab – raised floor	Security of space for smooth cold flow	1,000 ㎜
Building requirements	Raised floor-ceiling	Security of space for computing equipment installation and warm return	More than 5,000 ㎜ (down-flow)
	Infrastructure room floor level (slab–slab)	Acceptance of infrastructure equipment	8,000 ㎜ ~ 9,000 ㎜
	Width of computer equipment room	Consideration of the cold air reach of the thermo-hygrostat	1,200 ㎜ ~ 1,800 ㎜
	Computer equipment and large equipment introduction facility	Cargo elevator installation	More than 3,000kg
		Installation of equipment entrance (infrastructure facility room)	
	External blocking	Computer equipment room window finishing considering security and HVAC efficiency	
	Water pipe equipment	Completely insulated installation of water pipe equipment in computer equipment room	

	Computer equipment room – adjacent floor	Floor and ceiling condensation prevention and waterproofing	
	Building core structure	Side core type recommendation considering computer room isolation and facility access	
		Electric pipe shaft, telecom pipe shaft, pipe shaft configuration	
		Generator year installation	At least a 10-hour live load test
Power facility	Incoming and distributing panel facility	Commercial electric faucet through separate substation	Redundancy
		Dedicated power substation facility backup configuration for computer centre	N+1
	Power supply	UPS and HVAC power supply separation	
		Extension of power supply path	Redundancy
	Ground configuration	1 type (10ohm or less) independent grounding facility for computer equipment	Subject to local legislation
	Power monitoring	Status monitoring of power use for incoming and distributing panel	
	Surge protection	Surge protection device installed in the main distributing panel supplying computer equipment	
Power plant facility	Emergency generator	Centre emergency generator installation	N+1
		Power on UPS and HVAC simultaneously	
		Oil tank installation for 36 hours	
		Automatic switching configuration through automatic transfer switch in case of power failure	Consider arc and spark control
UPS facility	UPS facility	UPS installation and capacity calculation considering power factor and margin	
	Battery	Based on 20 minutes battery backup time	
		Maintenance-free sealed battery for UPS	
Constant temperature and humidity equipment	Thermo-hygrostat	Installation of thermo-hygrostat in computer room	N+1
		Thermo-hygrostat installed in UPS and battery room	
	HVAC circulation	Cold air discharge, upper return method	
	Leakproof	Installation of water collecting well to prevent leakage in the computer equipment room	
Firefighting facility	Extinguishing gas	Use of eco-friendly fire extinguishing agent in consideration of human body and environmental impact and extinguishing performance	
	Protective zone	Computer room and infrastructure facility room	
Security facility	Video surveillance facilities	CCTV surveillance facilities without blind spots	20 frames/second minimum
		More than 3 months of recording information	

		24-hour monitoring	
	Access control facilities	Establishment of access control facility for computer room and main infrastructure facility room	
		Dual safety system function with multi-level password (fingerprint, radiofrequency identification)	
		Control operation of single point of entry	
		Installation of tail-gating prevention equipment	
Computer equipment room	Steel gypsum panel partition wall installation	Use of non-combustible material (2 hours)	
		Waterproof, leakproof sealed partition	
	Cage partition installation	Separate installation by each tenant (H: A / F + 2,200mm)	
	Raised floor installation	Use of conductive tile panel	
		Floor epoxy finish	
		HVAC grill panel installation	
		More than 600 ㎏/m^2 of concentrated load	
	Raised floor installation location	Computer room, operation room	
	Secondary UPS power supply	Installation of distribution board installation for supplying computer equipment of UPS power	Redundancy
		3-phase, 4-wire 380/220V power supply	Redundancy
		Power supply to single power equipment through small static transfer switches (rack type)	
	System grounding	Separate installation of telecommunications equipment and server equipment	
		Raised floor bottom net ground installation	
	Implementation of “green” centre	Rack layout considering cold-heat corridor configuration	
		Efficient air circulation through raised floor and HVAC grill	
Computer room	Tray installation	Separate installation of telecommunications and power cable tray Power tray is installed under the raised floor Telecommunications tray is installed at the top of the rack	
		Maintenance of separation distance to prevent electromagnetic interference of telecommunications and power cables	
	Light	More than 300Lux in computer room	

	Exclusion of galvanized products	Exclusion of galvanized products from raised floors, ducts, thermo-hygrostats and trays to minimize the impact of computer equipment due to zinc oxide	
	Firefighting equipment	HFC-23 Package Modular Type application, installation of raised floor detection facilities	
Operating system	Infrastructure facility linkage operation	Linkage with constant temperature and humidity, firefighting and security facilities in case of emergency	
Operating system	Infrastructure facility monitoring system	Construction of dedicated system for monitoring centre infrastructure facilities	
		Power facility, UPS facility monitoring	
		Constant temperature and humidity facility, detection the leak monitoring	
		Security facility (CCTV, access control) linkage	
		Firefighting facility linkage monitoring	

Appendix 2. Terrestrial Cable Networks

1. Viet Nam–Hong Kong Cable 1

Path: Ha Noi, Viet Nam – Chai Wan, Hong Kong
Detailed route: Ha Noi – Lang Son / Dongdeng – Pingxiang – Chongzuo – Nanning – Guangzhou – Dongguan – Shenzhen – Chai Wan, Hong Kong

Figure 29: Viet Nam–Hong Kong 1 terrestrial network diagram

Source: China Telecom, "Greater Mekong Transmission Solution".

2. Viet Nam–Hong Kong Cable 2

Path: Ho Chi Minh, Viet Nam – Ha Noi, Viet Nam – Chai Wan, Hong Kong
Detailed route: Ho Chi Minh – Ha Noi – Lang Son / Dongdeng – Pingxiang – Chongzuo – Nanning – Guangzhou – Dongguan – Shenzhen – Chai Wan, Hong Kong

Figure 30: Viet Nam–Hong Kong 2 terrestrial network diagram

Source: China Telecom, "Greater Mekong Transmission Solution".

3. Cambodia–Viet Nam–Hong Kong Cable

Path: Phnom Penh, Cambodia – Ha Noi, Viet Nam – Chai Wan, Hong Kong
Detailed Route: Phnom Penh – (Ho Chi Minh) – Ha Noi – Lang Son / Dongdeng – Chongzuo – Nanning – Guangzhou – Dongguan – Shenzhen – Chai Wan, Hong Kong

Figure 31: Cambodia–Viet Nam–Hong Kong terrestrial network diagram

Source: China Telecom "Greater Mekong Transmission Solution".

4. Lao PDR–Hong Kong Cable

Path: Vientiane, Lao PDR – Chai Wan, Hong Kong
Detailed route: Vientiane – Luang Mamtha – Mengla – Jinghong Pu'er – Kunming – Pingxiang – Nanning – Guangzhou – Dongguan – Shenzhen – Chai Wan, Hong Kong

Figure 32: Lao PDR–Hong Kong terrestrial network diagram

Source: China Telecom, "Greater Mekong Transmission Solution".

5. Myanmar–Hong Kong Cable

Path: Ruili, Myanmar – Chai Wan, Hong Kong
Detailed route: Ruili – Dehong – Baoshan – Dali – Chuxiong – Kunming – Pingxiang – Nanning – Guangzhou – Dongguan – Shenzhen – Chai Wan, Hong Kong

Figure 33: Myanmar–Hong Kong terrestrial network diagram

Source: China Telecom, "Greater Mekong Transmission Solution".

6. Singapore–Bangkok, Thailand

Path: Singapore–Bangkok, Thailand

Detailed route: Equinix PoP, Singapore – Malaysia Terrestrial – Menara Ansar CBS – P.Besar CBS – Malaysia – Thailand Terrestrial – HYI CBS – Bangkok PoP

Figure 34: Singapore–Thailand terrestrial network diagram

Source: China Telecom, "Greater Mekong Transmission Solution".

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